

# MONTHLY WEATHER REVIEW

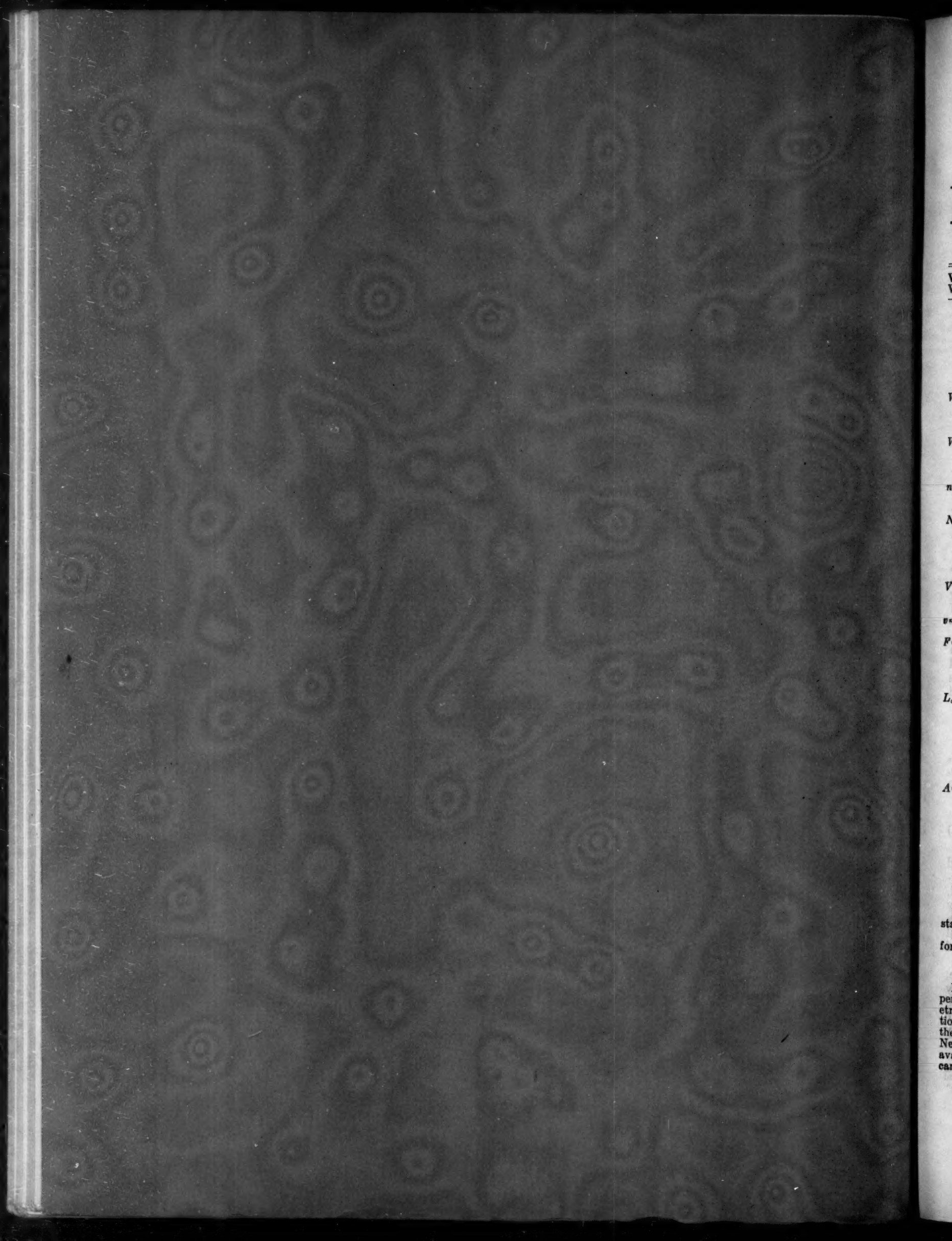
FEBRUARY, 1932

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UNITED STATES DEPARTMENT OF AGRICULTURE  
WEATHER BUREAU  
WASHINGTON, D. C.



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# MONTHLY WEATHER REVIEW

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## A RATIONAL THEORY OF THE CUP ANEMOMETER

By CHARLES F. MARVIN

NOMENCLATURE AND SYNOPSIS

$W$  = true wind travel in unit time. (To be specific in this text and to accord with universal American usage, I shall generally use inches for cup wheel dimensions, and express wind travel in miles per hour.)

$W_0$  = a small wind movement just adequate to keep a cup wheel turning against friction. The approximate value of this constant can be assigned by judgment or otherwise if specific observations are wanting.

$n$  = observed number of cup wheel turns during time,  $t$  seconds. This is the only fundamental performance-index of a cup wheel that can be directly measured during a test; velocity =  $n \div t$ .

$N$  = number of cup turns per unit wind travel at assumed uniform velocity  $W$  miles per hour =  $3600n \text{ (sec.)} \div tW$ . Observations show that the value of  $N$  drops to zero at certain low wind velocities, increases rapidly and approaches a limiting high value for each particular instrument as the wind attains hurricane speeds.

$V$  = wind travel indicated by any cup wheel, that is the number of mile marks recorded in one hour, or the indicated velocity by some scale.

$v$  = linear travel in unit time of cup wheel centers corresponding to actual wind travel,  $W$ .

$F$  = actual anemometer "factor" =  $W \div v$ . This is not a constant as often assumed and asserted. It is large at low velocities, falls off rapidly as wind speed increases, and at high velocities approaches a limiting low value which corresponds reciprocally to the limiting high value of  $N$ .

$L_{eff}$  = a single conventional symbol which denotes the five essential form and dimensional characteristics of cup wheels, namely,  $L$ , the length of arms from axis to center of open face of cup;  $c$ , the number of cups;  $d$ , diameter of cup involving also diameter of arms if not quite negligible;  $f$ , the form of cups, whether hemispherical, cylindrical, conical, parabolic or otherwise;  $f_s$ , the friction characteristics, especially at low velocities.

$A$  = the anemometer "index." This is an entirely arbitrary but indispensable number which must be incorporated in the gear train or other indicating scale of every instrument. It represents the constant number of cup wheel turns per mile mark, that is, of each registered or otherwise indicated mile of wind travel.

By definition and rigorous analytical relations, for English units

$$NF = \frac{10084}{L_{eff}}$$

By this equation it is the product  $NF$  which is rigorously constant for any one cup wheel, not  $F$  alone, as often asserted.

By definition the number of cup wheel turns per hour in a uniform wind,  $W$  is given by the following equation of identity:

$$NW = AV \quad (I)$$

For finite and positive values of  $N$  and  $W$  this is a rigorous and perhaps the most important fundamental equation in all anemometry. Its practical utilization, however, requires an analytical relation between  $N$  and  $W$ . The derivation of this is a problem in theoretical aerodynamics which has not yet been solved adequately. Nevertheless, from the empirical analysis of all the observations available it is found that the performance of all cup wheels tested can be accurately represented by equations of rectangular, hyper-

bolas whose asymptotes are parallel to the coordinate axis. The equation is

$$N = \frac{b(W - W_0)}{W + a} = \frac{10084}{LF} \quad (II)$$

The constants  $b$  and  $a$  must be evaluated from an adequate body of observational data over as great a range of values of  $W$  as possible.

Replacing  $N$  in (I) by its value in (II) we got a final unique equation for all cup anemometers.

$$V = \frac{\frac{b}{A}(W - W_0)}{1 + \frac{a}{W}} \quad (III)$$

The constants  $W_0$  and  $a$  are small and very nearly the same for all cup wheels. The equation is universal for all instruments because we are free to give  $A$  such a value that the ratio  $b \div A$  is the same for any design cup wheel we may wish to employ. This forcefully demonstrates that whether the indicated velocity,  $V$ , agrees closely with  $W$  depends quite wholly upon the value chosen for  $A$  in equation (III) and not as some suppose and assert upon the dimensional characteristics of the cup wheels themselves, which characteristics are effective almost exclusively in changing the value of  $b$ .

Observational data are as yet too meager to formulate the values of  $b$  and  $a$  in their full relations to wheel dimensions. From all the data we have we find the value of  $b$  for any cup wheel with arms ranging from 2.5 inches to 9 inches, and with 3 or 4 cups from 4 to 6 inches in diameter, can be quite accurately computed by the equation

$$b = \frac{5247.8 - 17.78 L}{L + 0.7976} \quad (IV)$$

### INTRODUCTION

In 1888 the writer brought to completion an investigation to find corrections to deduce the true from the indicated wind velocities which were being obtained by the use of the standard Weather Bureau anemometer, composed of four hemispherical cups 4 inches in diameter on arms about 6.72 inches long and assumed to make 500 turns per mile of wind travel, regardless of the wind velocity.

The investigation consisted, first, of tests conducted in the great closed court of the Pension Building by means of a large hand-driven whirling machine. Owing to the limited power available the maximum test velocities just reached 35 miles per hour. Second, the tests were extended to a maximum indicated wind velocity of about 50 miles per hour (true velocity about 40 miles per hour) by open air comparisons on Mount Washington, N. H., in which flat pressure plates exposed normally to the wind were used to check the extension of results to the higher velocities.

Notwithstanding the limited and very simple apparatus employed in these quite amateurish investigations, the results attained have stood the test of time in a highly remarkable manner.

In order to permit of calculating corrections at velocities far beyond those observed in the tests, a special form of purely empirical equation was adopted, which in the judgment of the writer seemed to safely extend the performance of the anemometers up to 90 or 100 miles per hour indicated velocity. The formula is:

$$\log W = 0.509 + 0.9012 \log v$$

$W$  = true velocity,  $v$  = linear velocity of cup centers. The gear train of these instruments is such that the linear cup velocity is one-third the indicated velocity.

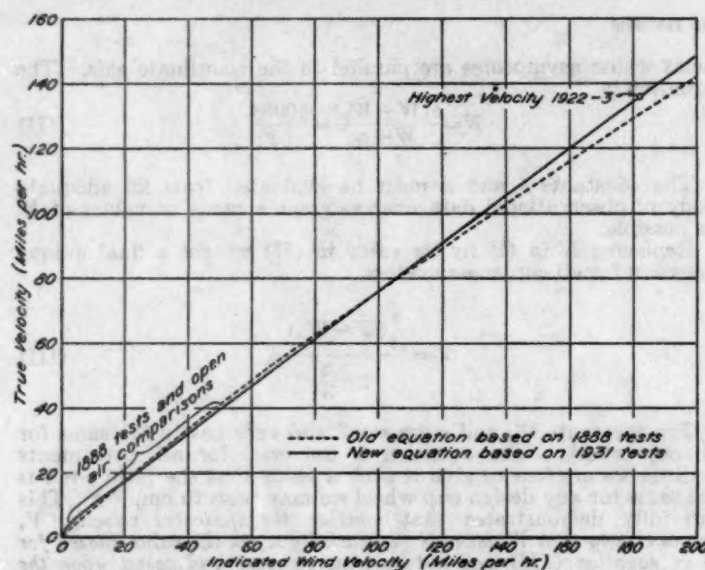


FIGURE 1.—Representing comparison between indicated and true wind velocities for the old standard 4-cup anemometer, geared 500 turns per mile, as computed by the logarithmic equation deduced from experiments in 1888, based upon tests below 50 miles per hour, and the new equation based on tests at the Bureau of Standards in 1922-29, at a maximum velocity of nearly 140 miles per hour

The dotted line in Figure 1 shows this equation over the range of true wind (scale at left) from 0 to 140 miles per hour. The full line in the same diagram shows the true relation between indicated and actual velocities for identically the same anemometer forms. This line is based on the tests made during 1922, in the wind tunnels at the Bureau of Standards, by Messrs. Fergusson and Covert of the Weather Bureau staff.

Since 1890 the bureau has disseminated tables of anemometer corrections based on the logarithmic curve extended up to 90 miles per hour, but it continued to enter indicated velocities in its records, believing that the correction tables should await further verification at high velocities before the actual application of corrections to the records was justified. The diagram clearly demonstrates that the velocity given by the logarithmic equation does not differ from what we now believe to be the true velocity by as much as 1 mile per hour, until a high velocity of at least 110 miles per hour indicated velocity is attained.

The equation for the full line is the new rational theoretical equation which it is the purpose of this paper to explain and discuss.

The line is a portion of an hyperbola having the following general equation:

$$V = \frac{b'W^2 - f'W}{W + a'}$$

The terms in this equation are,  $V$  = indicated velocity,  $W$  the true velocity of the wind,  $b'$  is the principal constant and is a function of the number, form, and diameter of cups, length of arms, friction of the instrument, etc. The term  $f'$  is a special friction factor depending upon the friction at very low velocities. Finally,  $a'$  is a small constant which defines the position of one of the asymptotes of the hyperbola; thus when  $W = -a'$ ,  $V = \infty$ , that is, the axis of  $V$  is parallel to one asymptote.

This form of equation is found to fit all the tests made by Fergusson and Covert, which include a total of more than 100 individual tests<sup>1</sup> on various cup wheels of the old standard type, all assumed to be practically identical. Some cup wheels were of copper, some, rather lighter, of aluminum; some with, others without, bracings; the spindles in some cases turned in ball bearings, in plain bearings in other cases.

Many additional tests were made on a wide variety of 3-cup wheels ranging from small kite anemometers to the largest, consisting of 6-inch cups on 3.56 inch arms. It is clear that the hyperbolic equation suffices to represent all these tests in a very satisfactory manner.

With this introductory description we pass at once to a theoretical survey of the problem.

**Technical considerations.**—Whenever any anemometer cup wheel or other form of rotation anemometer is placed for test in a wind stream which flows at either a steady or variable known speed, there is just one important aerodynamic effect which can be most easily and most accurately measured of all. That is the number of revolutions of the rotor per minute or second. This feature of cup wheel performance is a fixed invariable characteristic of each particular cup wheel or other rotor at each particular velocity, and is wholly independent of any arbitrary artificial assumptions or any kind of control on the part of the operator.

Passing over all of the methods commonly well known to all students of anemometry for measuring cup wheel performance, the best and most direct methods give us two simple numbers,  $n$  = number of rotor turns executed in time,  $t$  seconds, from which

$$n + t = \text{cup wheel turns per second}$$

With these data are of course associated the true velocity,  $W$ , of the wind stream causing the cups to rotate. Accordingly, for American anemometers intended to measure wind in miles per hour we may write

$$\frac{3600 \cdot n}{tW} = N \quad (1)$$

That is,  $N$  = number of cup wheel turns per unit wind travel. This is the most basic and fundamental performance-index of any cup wheel that can be formulated. It is a specific datum for each wheel. All tests of any consequence show that it is definitely a variable, not a constant, and a function of  $W$ , and the fixed dimensional characteristics of the cup wheel, including the friction of the revolving mechanisms which carry the wheel.

Any one who watches the behavior of, say two or more, of the standard Weather Bureau anemometers when freely exposed near each other in very light winds, can not fail but be impressed by the fact that at times some of the cup wheels will stand motionless, others will just barely turn, while some may possibly turn visibly faster.

<sup>1</sup> Throughout this paper the word "test" is used to designate any operation out of which we secure two comparable items of data; (1) the true velocity of a stream of wind (assumed to be reasonably uniform), (2) the angular velocity of the rotor of the anemometer exposed in the wind stream.

These features of characteristic behavior can easily be tested and observed on almost any quiet early morning. Differences in air currents affecting the several instruments, although a factor, do not explain the effects. The instruments may differ, or they may all be nominally identical but differ slightly in friction. Without further analysis we all know, of course, that all cup wheels cease turning at some very low wind movement. Is it not absurd to affirm that just because the recent standard 3-cup wheels are alleged to make 640 turns per mile of considerable wind movement, they also continue to make 640 turns per mile when the wind is so light that it is just able to keep the cups turning? Instead, the cups make only a small number, perhaps only 100 or 200 turns per mile. The number per mile increases rapidly as the velocity increases, and finally, as conclusively shown by the observations, the value of  $N$  for a given cup wheel asymptotically approaches an upper limit.

**True anemometer factor.**—All authorities and writers, if asked to define the term "factor" as used in anemometry, will doubtless answer, it is the ratio  $F = W/v$ , the ratio of the true wind velocity divided by the linear velocity of the cup centers. We can not assume a value for either  $F$  or  $v$ . We can not measure either of them directly. All we can do in making a test is to select a value of  $W$  and take the values of  $F$  and  $v$  just as they come by computation from the test. The only basic equation for this purpose is the following, in which  $L$  = length of arms in inches.

$$v = \frac{2\pi L N W}{5280 \times 12}$$

Transposing the terms

$$N \frac{W}{v} = N F = \frac{10084}{L_{eff}} \quad (2)$$

**Cup-wheel characteristics.**—The composite symbol  $L_{eff}$  is offered to designate the five essential characteristics of any cup wheel, as follows:  $L$  = mean distance from the axis to the center of the open face of the cups;  $c$  = number of cups, doubtless limited to 3 or 4;  $d$  = diameter or like dimension of cups, including arm features if essential;  $f$  designates the form of cups, whether hemispherical, cylindrical, parabolic, conical or other form; finally,  $f_0$  represents the friction characteristic of the cup-wheel axis, especially at low velocities.

For any one cup wheel (waiving deformations and slight variations of friction), each one of the five features is of course fixed and invariable in one and the same instrument, but variations in any one of the features in different wheels must be reflected in the value of  $N$  for a given value of  $W$ . However, all the observations available clearly indicate that variations in  $L$  are most influential in causing values of  $N$  to differ widely for different cup wheels. Since for one and the same wheel the second member of equation (2) is rigorously a constant, and since all observations show  $N$  varies from low to high velocities, obviously it is the product  $N F$  which is always rigorously a known constant and never  $F$  alone. This known constant depends primarily upon  $L$ , but nevertheless is subject to certain small secondary effects due to the characteristics  $cdff_0$ . The observational data as yet available are not sufficiently extensive and refined to permit the effects of these features to be definitely evaluated. It is clear, however, that they are small, and having adequately discussed the significance of the subscripts they may be

suppressed hereafter, provided the effects themselves are remembered and considered in subsequent developments.

If we regard  $L$  in equation (2) as a constant subject to changes by steps at will, the equation represents a family of rectangular hyperbolas whose asymptotes are the coordinate axes.

Figure 2 shows these curves for cup wheels with arms from 1 inch, which is quite too small for any practical measuring instrument, up to the great Kew anemometer with arms 24 inches long. This latter may possibly be quite too large for practical cup wheels, but to the student who appreciates the full significance of Figure 2, it is plain that cup wheels with arms at least 7 inches long or even longer, have a number of superior advantages; lower angular velocity, nearly the same value of the factor for similar values of  $N$  and for arms of quite different lengths.

All I have said under this caption of *true factor* relates rigorously to equation (2). Repeating somewhat for emphasis, we are free to select any cup wheel we please

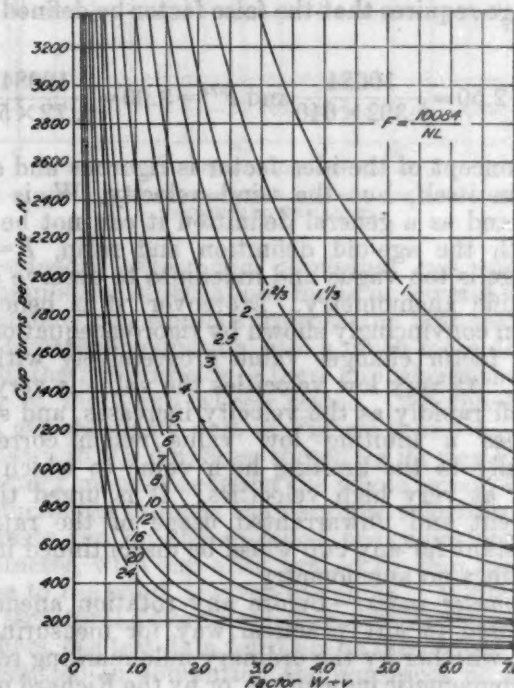


FIGURE 2.—Family of curves showing values of anemometer factor,  $F$ , in relation to the turns per mile,  $N$ , and the length of cup wheel arms,  $L$ , in inches, indicated by numbers on the line

and we may choose approximately the wind velocity for a test. Once exercised these choices end it. We have no *a priori* control whatever over the values of either  $N$ ,  $F$ , or  $v$ . They must be taken just as they come from the test and computations. Emphasis is laid on these matters in order to call attention to what I regard as untenable reasoning on the part of anyone who saddles upon the equation  $n+t$  = revolutions per second, the artificial assumption that a single turn of a cup wheel represents, say one meter or one one-thousandth of a mile, or any other unit of wind travel. At the very best, the assumption can be true for only some one wind velocity, and that an unknown one. Moreover, to make such an assumption at the outset is to presume already to know that which it is the main purpose of the investigation to ascertain.

It has been clearly shown that upon the basis of its definitions alone, including rigorous equations of relation, there can not be any such thing in practical anemometry as cup wheels with "constant factors," except by ignoring friction effects at low velocities and disregarding small

but important and significant changes at high velocities. All such assumptions and approximations only becloud clear thinking and obscure the more important facts sought in any serious investigation. Moreover, they tend to suppress and minimize the real errors of those cup wheels which are said to have constant factors, and even lead to the false conclusion that some particular cup wheel gives true wind velocities over a wide range without the need of tables of correction, whereas its real errors are large.

*False "factors."*—If we answer such questions as, What is the factor for the new 3-cup anemometer? The old 4-cup standard? etc., by saying that the factor is 2.50 for the 3-cup instrument and originally 3.00 for the old standard, we are using the word factor loosely with an entirely different definition from that prescribed by equation (2). The gear train<sup>2</sup> and dial subdivisions including electrical registration devices in these instruments indicate 1 mile of wind travel for each 640 cup wheel turns in the 3-cup wheel and 500 turns of the old standard. Our unwitting loose usage requires that the false factor be defined by the equation

$$F' = 2.50 = \frac{10084}{6.302 \times 640} \text{ and } F'' = 3.00 = \frac{10084}{6.72 \times 500}.$$

This concept of the idea factor is rigorous and specific enough in itself, but the wind velocity,  $W$ , is wholly omitted and as a general definition it can not be reconciled with the age-old definition and ratio,  $F = W + v$ . This usage is too vague and indefinite to deserve a place in scientific anemometry. Moreover, it is believed to have been convincingly shown by rigorous equations that the true factor changes value progressively with wind velocity. At very low velocities the value is very large. It falls off rapidly as the velocity increases, and steadily approaches a limiting low value which corresponds reciprocally to the limiting high value to which  $N$  approaches at very high velocities. It is urged that the inconsistent and unwarranted usage of the ratio  $W + v$  as a constant for any cup wheel be discontinued in scientific writings on anemometry.

*Anemometer index.*—Before any rotation anemometer can be used in any practical way for measuring wind velocity, whether by the ordinary mile-marking registers, by electromagnetic indications, or by the Richard method, it is first necessary to choose a definite index number,  $A$ , which is rigorously a constant and which must be incorporated in the gearing and other registration arrangements of the instrument. This number is 500 in the old standard 4-cup anemometer and 640 for the new 3-cup wheels. They are respectively the number of cup-wheel turns alleged to indicate a mile of wind travel. By definition and fact this number, when incorporated in the gear train, becomes absolutely a constant for all wind velocities for each anemometer to which it is given, and no instrument can be used without a number. Up to the present time this indispensable number has never been given a specific name. How fortunate it would have been had Robinson called this number the anemometer "factor," or perhaps its index, instead of supposing the ratio  $W + v$  was a constant and calling that variable the factor.

Brushing away the fallacious thesis of assuming a factor and computing a value of  $A$  to correspond, it is easy to show that the choice of a value for  $A$  is purely an arbitrary matter, although a wise choice must of course

be made. It is wrong, for example, to say that the 3-cup anemometer indicates more nearly true wind velocities over the entire range than the old 4-cup standard itself. It is altogether a choice of the index number.

A method for the wise choice of the index number will be given presently. In the meantime it is urged that proper recognition be accorded to this important arbitrary number designated  $A$  and defined thus:

$A$  = anemometer index = the arbitrary number of cup-wheel turns chosen to correspond to the registration of so-called mile marks or other scale values of indicated wind travel.

*Final general equation.*—Let  $V$  = the number of mile marks recorded or otherwise indicated in one hour at any time when the wind travel is  $W$  miles per hour and the cups make  $N$  turns per unit wind travel. Purely from these definitions we may write at once, as an equation of identity

$$NW = AV \quad (3)$$

For positive values of  $N$ ,  $W$ , and  $V$ , both sides of this equation express simply the total number of cup-wheel turns per hour, and the equation is the basic fundamental equation for all anemometry. Every investigation ever made over any range of velocity shows  $N$  is a variable; therefore it is physically impossible for  $V$  to be the same as  $W$  for any cup wheel, except at some velocity depending upon the choice of  $A$ .

By replacing  $N$  in equation (3) by its value drawn from equation (2), we get a new rigorous equation between  $V$  and  $W$  involving  $F$  and the form and dimensional characteristics of a cup wheel, thus:

$$\frac{W}{F} = \frac{AV}{10084} L_{cups} \quad (4)$$

This equation is cited chiefly to show its availability to those who may prefer to follow up the analytical relationship between  $W$  and  $F$  rather than those between  $N$  and  $W$ . Both equations (3) and (4) rigorously satisfy all definitions equally, and values of  $N$  and  $F$  must be classed alike as direct observations which necessarily flow as specific results from each test measurement. (See values in Tables I, II, and III.)

Although independent computations of equation (4) have been made for both the copper and aluminum 4-cup wheel tests, it is so much simpler and more rational to use the  $NW$  relationship that that has been adopted as the regular program.

Throughout all the foregoing discussion of technical considerations, empiricisms of every sort have been studiously excluded, especially from the equations, and I have finally attained the rigid equations (3) and (4) giving the relation between an indicated wind velocity  $V$  and the true velocity  $W$ . The practical utilization of these equations requires that proper analytical relations be formulated between  $N$  or  $F$  and  $W$ . Theoretically this is a problem in the aerodynamics of cup-wheel performance, but unfortunately no satisfactory solution of it has as yet been offered, and we are compelled to seek some empirical solution which satisfies the rather considerable body of data now for the first time available. This leads us naturally to the next section.

#### TEST OBSERVATIONS AND THEIR ANALYSIS

Guided by the foregoing considerations, all the original observations made by Messrs. Fergusson and Covert on 3 and 4 cup anemometers normally exposed in the wind

<sup>2</sup> See caption Anemometer Index.

tunnels at the Bureau of Standards have been reduced to simultaneous values of  $W$ ,  $N$ , and  $F$ .

Tables 1, 2, and 3 contain the entire body of original data with explanatory and descriptive material. Column 2 gives the carefully observed velocity of the wind stream in meters per second.<sup>3</sup>

The third column contains the so-called indicated velocity on the basis explained in the caption to the tables. Column 4 contains the direct index,  $N$ , number of cup turns per mile of wind, freed from all arbitrary assumptions of any kind. The fifth column contains the actual so-called "factor" for the particular cup wheel under test and for each velocity. Finally, the column of specifications supplies the essential dimensions, etc., concerning the cup wheels and spindles.

**Measured track-walking tests.**—Very few of the wind tunnel tests were made at velocities as low as 10 miles per hour. They thus fail to show what happens at low velocities. To supply this information in a small way the writer instituted quite a number of tests in which various anemometers were carried on a staff by a person walking along a measured line or track laid off upon the balcony of the closed inner court of the Weather Bureau. The track was 0.0210 miles in length. A second person carried a small chronograph upon which the number of circuits around the court, the turns of the cup wheels under test, and the time were all accurately recorded. Velocities from under 1 to over 3 miles per hour were easily maintained in these tests.

The results confirmed the reasoning on low-velocity performance previously given and fitted in very well with the wind tunnel tests. Nevertheless, troublesome natural air currents, especially through open portals leading onto the balcony, caused some anomalous values of  $N$  and demonstrated the need of numerous tests and much care if exact values at the lowest velocities are to be secured. On the other hand, walking tests of this character under favorable conditions have great advantages over the use of ordinary small-sized whirling machines.

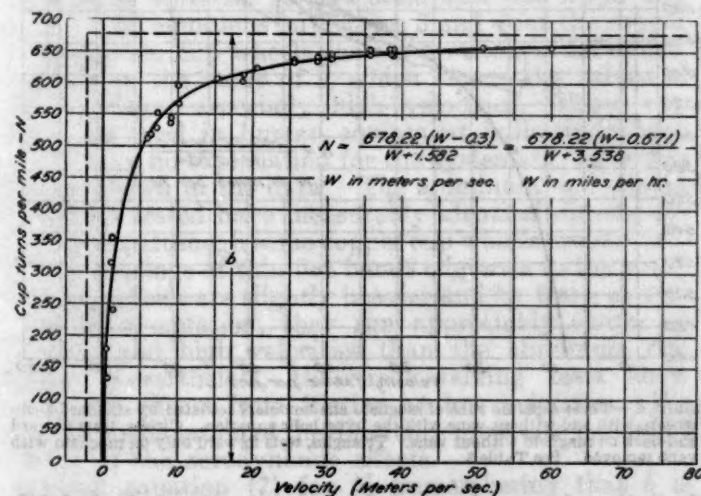


FIGURE 3.—Tests on old standard copper cup wheels with rectangular hyperbola, computed by equation as given on diagram

While the analytical theory already given under the caption Technical Considerations was in the process of gradual development, a survey was also being made by means of plots of various groups of observations taken

<sup>3</sup> Except in the case of the tests on the magneto anemometers, the original observations of wind velocity were made in meters per second. To avoid local inaccuracies entailed by rejection of decimals incident to conversions to miles per hour, the unit meters per second was retained throughout all the numerous least square computations. The conversion of the final equations to English units involved, of course, a very simple transformation of the constant with no loss in accuracy.

from Table 1, including the fitting of parabolas, arcs of ellipses, etc., to the data. Mr. Grimminger, who was assisting in the study at this time, casually pointed out that an equation of the form,  $N = \frac{bW-f}{W+c}$  might be useful. Trials soon proved this to be a happy suggestion. Obviously the curve is a hyperbola with its asymptotes parallel to the coordinate axes.

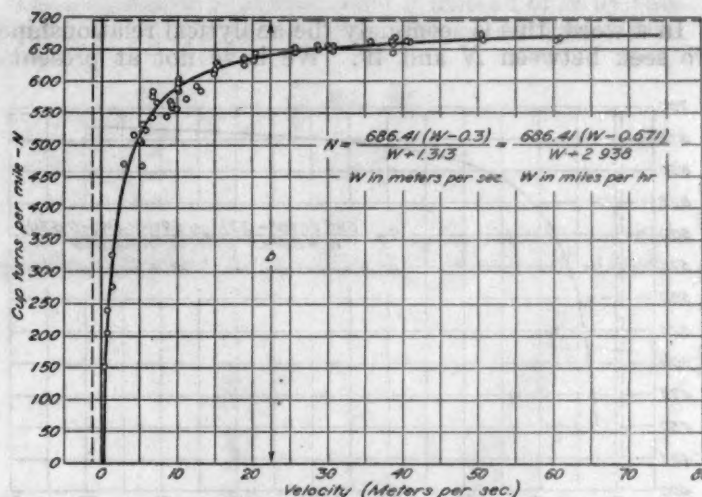


FIGURE 4.—Tests on aluminum cup wheels with rectangular hyperbola, as given by equation on the diagram

**Old-standard copper and aluminum cup wheels.**—The large number of observations made on several sets of the old-standard cup wheels furnishes the best test we have of the hyperbolic equation, also a much more dependable value of the performance of these cup wheels than of that of any of the 3-cup wheels tested. All the 4-cup test values are shown by dots in Figures 3 and 4. A line is also shown in the diagrams threading its way in a highly satisfactory manner between the whole series of observations, including those at the very low velocities.

A single run on the so-called heavy-pattern seacoast anemometer, with cup arms braced by thin metal bands flatwise to the wind, is given in run 33. While there are minor structural differences between this anemometer and the others, the test data for it are so discordant that they were omitted in computing the constants of the representative line. The seacoast cup wheel ran decidedly too fast at low velocities, although its known excess of friction should make it run too slow, whereas at high wind velocities, when friction is of less consequence, the wheel ran altogether too slow. The causes for these results are quite unexplained, unless due to excessive friction under lateral pressure in the top bearing or the wind resistance of the flat bands.

In Figure 4 are shown the 68 test observations upon four different sets of aluminum 4-cup wheels. The representative line threading its way through the somewhat more scattered observations in this case is also shown.

Figure 5 with the computed line and its equation represent tests from a single run on 3-cup wheel No. 30, which is the only 3-cup wheel originally tested having dimensions closely comparable with the so-called 3-cup standard anemometer subsequently adopted. Finally, Figure 6 represents three series of tests of standard 3-cup anemometers carried on Friez magnetor indicating mechanisms, as explained in the heading of the table.

A considerable variety of 3-cup wheels with other dimensions also were tested, generally only in a single run, as shown in Table 2. Equations have been computed for

all of these runs, and it is found that with few exceptions they are all well represented by a rectangular hyperbola whose asymptotes are parallel to the coordinate axes. These asymptotes are shown on the drawings by heavy broken lines. The general equation for the lines threading through the observations in a form most convenient for computing its constants by least square methods is

$$f + bW + aN + NW = 0 \quad (5)$$

In a word, this is seemingly the analytical relationship we seek between  $N$  and  $W$ . We have not at present

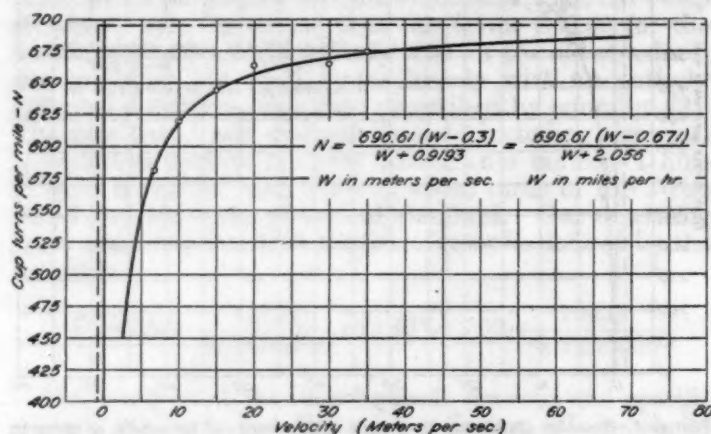


FIGURE 5.—Single run of tests on cup wheel No. 30, like the 3-cup standard wheel finally adopted, with equation of hyperbola

any rigorous aerodynamic proof that this form of equation should represent the  $NW$  relationship, but its strongest claim for acceptance is that it seems to fit all observations available from the very lowest to the highest velocities, especially for those types of cup wheels which are best suited to meet meteorological requirements. The numerical constants for the several cup wheels are given in the equations on the diagrams and in Table 4, to follow.

To discuss these equations briefly, it will be noticed that the coefficient  $b$  in equation (5) always takes on the negative sign, and from the diagrams we see that as an ordinate,  $b$  fixes the position of the asymptote parallel to the axis of  $W$ . Also that  $b$  is the limiting large value which  $N$  asymptotically approaches as the wind velocity becomes very high. It is also plain from the diagrams that the abscissa,  $W = -a$  locates the other asymptote parallel to the axis of  $N$ .

Finally, when  $N = 0$ ,  $W = -\frac{f}{b}$ . This introduces a very

important relation involving the effects of instrumental friction which deserves rather full analysis.

**Friction.**—Little experimental data of any kind are available by which the quantitative effects of friction in anemometry can be evaluated. Friction generally is regarded as negligible, and in fact is relatively unimportant in instruments of good design if they are occasionally oiled and otherwise properly cared for. Nevertheless, its effects can not be ignored, especially in the case of winds of low and moderate velocity or in any serious theoretical analysis. Two aspects of the question require consideration.

(a) There is the irreducible minimum of the friction which operates when the cups are turning in very light winds and which may stop rotation altogether while the wind continues to move at some very low velocity,  $W_0$ , which I assume is just high enough to keep the cups

turning. In this concept of  $W_0$  we must discriminate between friction of rest, which is often greater than the irreducible minimum friction of slight motion.

(b) The second effect of friction, about which still less is actually known than the (a) effect, is due chiefly to the sliding action of the spindle in the top bearing. Increase of wind causes this to increase nearly as the square of the velocity and operates to lessen the number of cup wheel turns per unit of wind travel which would be attained at high velocities if all friction were zero.

All friction effects are controlled and minimized by the use of high-grade construction, and especially the adoption of correctly designed ball bearings.

Although certain of the wind tunnel tests were made with ball bearings and others with plain sliding bearings, the small quantitative differences can not be segregated from large accidental fluctuations of unassignable causes. This of itself may indicate that friction in first-class instruments on the whole is small and unimportant, except at low velocities, which I shall now consider somewhat further.

Transposing the terms in the equation  $W_0 = -f + b$  we get,

$$f = W_0 b \quad (6)$$

The quantity  $W_0$  must always have a small and positive finite value; and since  $b$  is always negative,  $f$  is therefore positive. In effect, this constant measures the frictional resistance of the cup wheel mechanisms at low velocities; that is,  $W_0$  is the low velocity which is just sufficient to keep the cup wheels turning against the friction of the bearings. If we have a strong body of observational data at low velocities to statistically balance the numerous results of high velocity tests, then reliable values of  $f$ ,  $a$ , and  $b$  will flow from a least square analysis

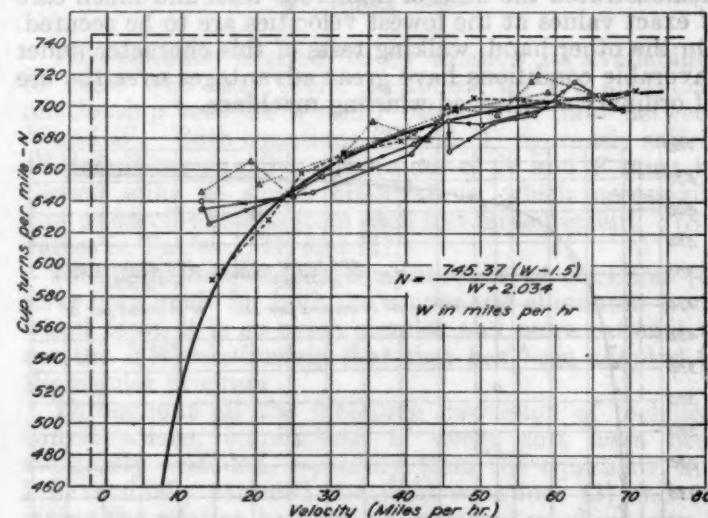


FIGURE 6.—Three separate runs of magneto anemometers actuated by standard 3-cup wheels, with and without vane, with the hyperbolic equation. Circles, tests forward and back on magneto without vane. Triangles, tests forward only on magneto with vane removed. See Table 3

of all the observations, and a trustworthy value of  $W_0$  will result from equation (6). Unfortunately, however, nearly all the wind-tunnel tests are at velocities above 13 to 15 miles per hour, which are quite too high to tell us anything about what the cup wheels do between 0 and 15 miles, which range in velocities represents perhaps more than 75 per cent of the velocities at ordinary meteorological stations. Under these circumstances the vagaries and inaccuracies in the high-velocity data will cause calculation of constants not controlled in any way to give values of  $W_0$  which may sometimes be too large,

or it may take on negative values which also is irrational. Although we have the few observations obtained by the track-walking tests, these are inadequate for all the cup wheels. Therefore, to assure that our final equations shall give rational values for  $W$ , I shall use equation (6) as an equation of condition in the least square computations. We know from the track-walking tests and other information that the value of  $W$ , must lie between one-half and  $1\frac{1}{2}$  miles per hour for most instruments, depending on what may be known about their friction. This enables us to replace  $f$  in the general equation (5) by its value  $f = -W_0b$ .

By this treatment the low velocity friction term is retained in the final general equation in the form  $W_0b$ , which can be evaluated at any time to satisfy any new knowledge that may be acquired as to the condition of an instrument and the best value of  $W_0$ . In subsequent equations  $bW_0$  will therefore take the place of  $f$ , and  $W_0 = -0.3$  has been used for computations when  $W$  is in meters per second except in the case of the magnetos and certain heavy cup wheels for which  $W_0 = -0.5$  is used.

The equation for actual calculation of the constants  $a$  and  $b$  thus becomes:

$$(W - W_0)b + aN + NW = 0 \quad (7)$$

Table 4 gives the values of the three constants for practically all the cup wheels tested whose dimensional characteristics are fairly comparable and suited to meteorological needs. With few exceptions the values of  $a$  in all the equations are small and nearly the same. Since  $a$  is the constant which gives curvature to the anemometer law, there is no justification for the statement sometimes made that the indicated velocities by one cup wheel are more nearly true wind velocities than are those by another. When the gear train—that is, the arbitrary constant  $A$ —is chosen with equal fairness to all, the run of hourly indicated velocity by all will be essentially identical, as will more definitely appear later.

*Systematic difference between aluminum and copper cup wheels.*—The equations on Figures 3 and 4 for the copper and aluminum cup wheels show a systematic difference, especially in the value of  $b$ , which affects the values of true velocities, especially high velocities. These cup wheels are used in bureau equipment indiscriminately, and we have no explanation for the systematic difference actually shown in the data. The aluminum and copper cup wheels tested have measurably identical dimensions throughout, although some copper cup wheels are strengthened by bracings of thin flat bands edgewise to the wind. Such cup wheels are slightly heavier and by tests, as well as by their equation, they run appreciably slower at moderate and high velocities than the aluminum cup wheels. Nevertheless, the track-walking tests show very small effects from friction at low velocities. We think the explanation of the difference must also be sought in some of the aerodynamic effects.

Solving equation (7) for  $N$  (remembering that  $b$  is negative) gives

$$N = \frac{b(W - W_0)}{W + a} \quad (8)$$

Replacing  $N$  by its value in terms of  $F$  from equation (2) gives the companion analytical relation between  $F$  and  $W$  as follows:

$$F = \frac{10084}{bL} \frac{(W + a)}{W - W_0} \quad (9)$$

Substituting for the value of  $N$  in the basic equation (3) its value from equation (8), and writing the resulting equation in a form to show its universality, we get

$$V = \frac{\frac{b}{A}(W - W_0)}{1 + \frac{a}{W}} \quad (10)$$

The companion equation, using  $F$  instead of  $N$  by substitution of (9) in (3) also gives after a few transformations,

$$V = \frac{\frac{F'}{b'}(W - W_0)}{1 + \frac{a}{W}} \quad (11)$$

The mathematician will, of course, readily see that equations (10) and (11) are literally equations of identity.

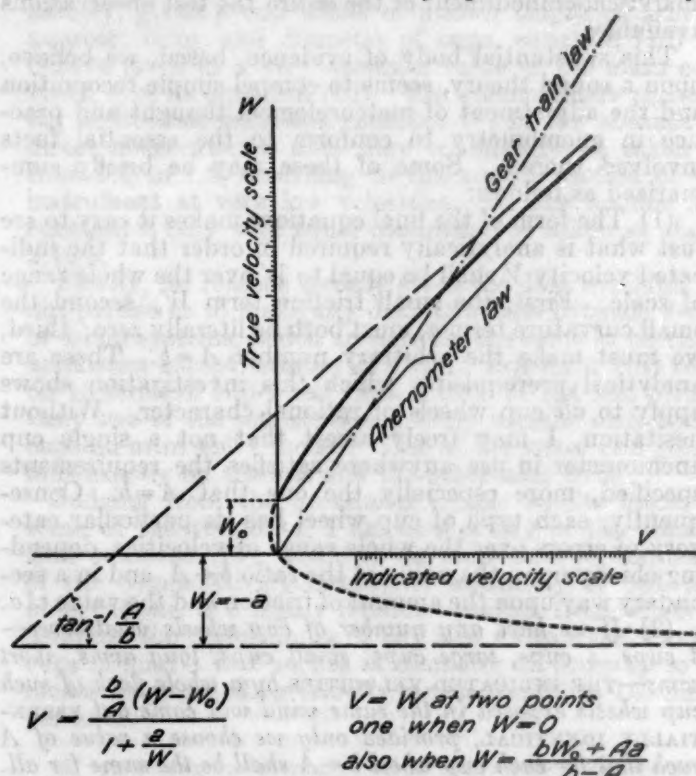


FIGURE 7.—Diagrammatic view, not to scale, of hyperbola representing anemometer law between indicated velocities  $V$  and true velocities  $W$

In (11)  $F'$  is the quantity I have called and defined as the "false factor," corresponding to the arbitrary index number  $A$  in (10). Also  $b'$  is the minimum value of the true factor, corresponding to  $b$  in (10), which is the maximum value of  $N$ .

Either of these equations, (10) is preferred, individually constitutes the final general equation for any cup wheel of reasonable dimensions.

Equation (10) or (11) is that of an hyperbola, of which one branch is such as shown in Figure 7. The dotted portions of the curve are, of course, not relevant to anemometry, but the full-line portion is believed to give the most exact analytical representation of cup-wheel performance yet offered. It covers the complete range of velocities from  $W = W_0$  to the highest velocities yet attained in any tests available for these studies.

One of the asymptotes of the curve is parallel to the axis of  $V$ , and it cuts the axis of  $W$  at the point  $W = -a$ .

The other asymptote makes an angle with the axis of  $V$  whose tangent is  $+\frac{A}{b}$ . The axis of the hyperbola and its intercepts with the coordinate axes can easily be evaluated by the methods of analytical geometry. It is obvious also that  $a$  is a small, nearly constant parameter of the equations which measure the curvature of the anemometer law.

The reader must remember that equations (10) and (11) represent not only the 101 test values on the copper and aluminum cup wheels, but in addition about 83 test values on 13 different sets of 3-cup wheels of widely varying dimensions. This representation embraces the entire range of velocities always from  $W=0$  to nearly 140 miles per hour in a small number of tests, and in all other cases to a limit of nearly 80 miles per hour. The agreement between observed and computed values is particularly satisfactory for those types of cup wheels best suited as standard instruments. In a word, these equations, including the values of the constants in Table 4, are the analytical embodiment of the entire 184 test observations available.

This substantial body of evidence, based, we believe, upon a sound theory, seems to compel simple recognition and the adjustment of meteorological thought and practice in anemometry to conform to the essential facts involved therein. Some of these may be briefly summarized as follows:

(1) The form of the final equations makes it easy to see just what is analytically required in order that the indicated velocity  $V$  shall be equal to  $W$  over the whole range of scale. First, the small friction term  $W_0$ , second the small curvature term  $a$ , must both be literally zero; third, we must make the arbitrary number  $A=b$ . These are analytical prerequisites which this investigation shows apply to all cup wheels of rational character. Without hesitation, I may freely assert that not a single cup anemometer in use anywhere satisfies the requirements specified, more especially the one that  $A=b$ . Consequently, each type of cup wheel has its particular category of errors over the whole range of velocities, depending chiefly upon the value of the ratio  $b+A$ , and in a secondary way upon the amount of friction and the value of  $a$ .

(2) If we have any number of cup wheels whatsoever—3 cups, 4 cups, large cups, small cups, long arms, short arms—THE INDICATED VELOCITIES by a whole flock of such cup wheels exposed in the same wind will come out ESSENTIALLY IDENTICAL, provided only we choose a value of  $A$  such that for each cup wheel  $b+A$  shall be the same for all.

Moreover, equation (10) gives us a substantial analytical basis justifying the statement that it is the choice of the constant  $A$  and the gear train of any particular anemometer, and not the choice of the form and dimensions of a cup wheel which determines how nearly  $V$  and  $W$  run in close accord over a given range of velocities.

The old standard 4-cup wheel on a gear train of 500 turns per mile was a misfit. On a gear train of 640 turns per mile its performance is superior to that of the present 3-cup standard.

(3) In the present stage of the science of anemometry we must give up the idea that there is some magical cup wheel whose indicated velocities are all nearly true velocities, and we must stop deceiving ourselves and others by suppressing or minimizing the real errors in indicated velocities by any cup wheel. The magic wheel has not yet been found. Its discovery depends upon identification of the aerodynamic features which cause the constant  $a$  in all equations to have a small positive finite value. When we find out how to design a cup wheel for which  $a$  will always be zero, then the hyperbola represented by equation (10)

becomes two intersecting straight lines. One of these coincides with the axis of  $V$ , the other intersects at the origin of coordinates, provided the low-velocity friction is absolutely zero. Finally, this line which is the portion of the hyperbola which represents the anemometer law,—this line will cross the axes at an angle of  $45^\circ$ , provided the arbitrary number  $A$  is made equal to the limiting value attained by  $N$  in very high winds. Under these conditions equation (10) (and (11) also with slight changes in terminology) reduces to the simple form  $V=W$ .

These entirely rational results which flow from certain limiting assumptions go a long way toward establishing the general soundness of the analytical basis upon which the final equations (10) and (11) have been formulated.

Choice of  $A$ .—While the indicated velocities by all cup wheels will be essentially the same if the ratios  $b+A$  are made identical, nevertheless this should not be the sole criterion for fixing upon the best value of  $A$  in any practical case. By the basic equation  $NW=AV$  it is plain that  $V=W$  for those values of  $W$  near to that value which makes

$$N'=A \text{ or } W'=\frac{bW_0+Aa}{b-A}$$

This is a useful equation to guide us in the choice of the best value of  $A$  for any given case. If, for example,  $A$  is chosen equal to  $b$ , then  $W'=\infty$ ; that is, the indicated and true velocities run in accord only at very high velocities and disagree seriously at moderate and low velocities. On the other hand, if  $A$  is made much smaller than  $b$ , then  $W'$  will have a small value; that is, the true and indicated velocities will agree closely at all low velocities, as in the case of the old 4-cup standard.

Obviously we must compromise so as to make  $V=W$  at some ordinary velocity, say 30 to 50 miles per hour, according to the relative importance we attach to the errors we must tolerate in uncorrected indicated velocities at moderate as compared with high velocities.

There is, moreover, a mechanical limitation upon the choice of  $A$ ; that is, its value must be a multiple of 10, otherwise the gear train becomes complex; that is, incommensurate ratios, fractional gear teeth, etc., may be involved. We must be content, therefore, with choosing the best value of  $A$  we can, and then compute from equation (10) a suitable table of true and indicated velocities.

It is very difficult to show graphically the actual errors of anemometers if we limit ourselves to plotting  $W$  against  $V$ ; that is, the relative smallness of the errors compel the use of graphs on a very large scale if details are to be brought out. However, better results with any desired degree of magnification, even in a small diagram, may easily be attained by means of a difference equation; that is, subtract  $W$  from both sides of equation (10) and after reduction we get

$$V-W=\frac{\left(\frac{b}{A}-1\right)W-\frac{b}{A}W_0-a}{1+\frac{a}{W}} \quad (12)$$

The numerator in this equation looks complicated because the make-up of its two constants is shown in full. In actual practice these reduce to a small coefficient for  $W$  and an absolute constant. For example, for the old aluminum 4-cup standard this equation is

$$V-W=\frac{0.3728W-3.8591}{1+\frac{2.938}{W}} \quad (13)$$

In this, and like equations to be given presently, it is obvious that  $V - W = 0$ , that is  $V = W$  when  $W = \frac{3.8591}{0.3728} = 10.4$  miles per hour. This means, as known since 1888, that between 0 and 15 miles per hour the indicated and true velocities agree closely by the old 4-cup standard, whereas above 15 miles per hour the indicated velocities run far in excess, all now shown to be due to the choice of the gear train of 500 turns per mile registration.

If we put the old standard 4-cup wheel on the 3-cup spindle geared 640 turns per mile registration, the equation becomes

$$V - W = \frac{0.0725W - 3.6577}{1 + \frac{2.938}{W}} \quad (14)$$

This gives a very satisfactory distribution of errors over the whole range of velocities.  $V = W$  when  $W = 50.5$  miles. There is a maximum negative error of almost 2.3 miles per hour at  $W = 11$  miles per hour, between this and 60 miles per hour the errors are relatively small and increase steadily. It will be shown presently that these errors by the 4-cup standard on the 3-cup spindles are decidedly smaller than those for the 3-cup wheel itself. These results are shown graphically in Figure 7.

**Relation of  $b$  to cup wheel dimensions.**—The climax and consummation of this study will be attained if we can formulate a satisfactory equation giving the relation between the proper value of  $b$  in equation (8) or (10) and the dimensional characteristics of the various cup wheels. In the absence of much more detailed information than we yet have of aerodynamic anemometry, we must rely upon the test data available for setting up the desired relationship. All the material we have for this purpose is found in the values of  $b$  given in Table 4.

The strong body of test observations on the old standard 4-cup wheels gave very definite values of  $b$  and  $a$  for 4-inch cups on arms 6.68 inches long. These data, of course, establish one strong point on any curve representing the  $b, L$  relations. For additional points we must rely upon tests made upon a wide variety of 3-cup wheels. With very few exceptions only a single test was made upon each wheel at only five or six velocities which included neither the lowest nor highest speeds. When we notice the seemingly erratic and conflicting values of  $N$  which result from numerous tests on the 4-cup wheels, including entirely similar conflicts in the few cases of more than one test on 3-cup forms we recognize the relative weakness of the 3-cup data based chiefly on single runs on a scattered variety of wheel forms.

The inadequacy of all the data at present available has already been stressed for making the nice discrimination necessary in order to evaluate by any numerical quantity the small effects caused by changes in cup-wheel characteristics,  $cdff$ . The solution of this must be left to the future, because setting aside for the present all questions as to the effects of form and friction, we find that during the tests the cup diameters and the length of arms were varied more or less indiscriminately; that is, both  $L$  and  $d$  were frequently changed small amounts simultaneously. It is, therefore, impossible to assign any specific effect to a change of either number or diameter of cups in any particular case. The tests show that a change of a few tenths of an inch in arm length makes a noticeable difference. Small changes of both factors simultaneously, coupled with the practice of making but a single run over a limited velocity range, combine to reduce the present study to setting up a relationship

between  $b$  and  $L$  as if the effects due to  $cdff$ , were negligible, which, of course, is hardly the case. More refined and extensive observations must become available, however, to remove this limitation on the present work.

Disregarding as more or less noncomparable the data for the small kite anemometers, and limiting our study to cup wheels with cups from 4 to 6 inches in diameter on arms 2.3 to 8.6 inches, I have selected 15 test values of  $b$ , two of which represent, respectively, the very strong body of results for the copper and aluminum old standard 4-cup wheels. All of these points are plotted in Figure 9. It is believed every reader will concede that the observations as a whole are well represented by the line running through them and whose equation is

$$b = \frac{5247.8 - 17.78L}{L + 0.7976} \quad (15)$$

This in part at least is the attainment of our objective, namely, given a cup wheel of known length of arm  $L$ , number, form, and diameter of cups, equation (15) we believe gives us a very accurate value of the main constant,  $b$ , of its equation (10). For anemometers registering in English units the constant  $W_0$  in the absence of direct observational data may confidently be taken at from 0.5 to 1.5, according to the known friction of the instrument at very low velocities. In like manner the constant  $a$  may with equal confidence be taken at about 2 to 3.

Finally, for reasons already given the data available do not permit us to make any discrimination between 3-cup or 4-cup systems, which are strictly the same in all characteristics except number of cups. Equation (15) rests on 15 series of cup-wheel runs, a total of 184 test points. Only two of the sets represent 4-cup wheels, with 4-inch cups on arms 6.677 inches. One of the latter two points falls exactly on the line and the other near to it.

Judging from the occasional erratic results found in some of the test data, I am confidently of the opinion that equation (15), which is the analytical embodiment of the comparatively consistent testimony of 184 test observations, is a highly reliable equation from which to compute the performance of any 3 or 4 cup wheel having cups around 4 to 5 inches in diameter on arms up to 10 inches long, including velocity ranges from 0 to 150 miles per hour.

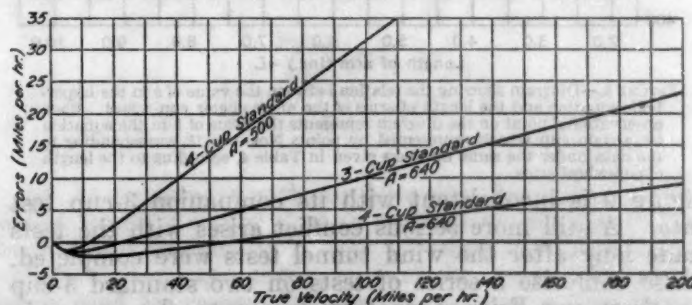


FIGURE 8.—Diagram showing differences between true and indicated velocities, in miles per hour, depending on the kind of anemometer and the value of the index number,  $A$

**Old and new standards contrasted.**—These extensive studies compel me to vigorously advocate the decided superiority of the old 4-cup type of instrument for the accurate and dependable measurement of wind velocity, especially of hurricane force. The mechanical construction of the old cup wheel must be improved upon and strengthened, but the 4-cup type of wheel with slightly longer arms has higher accuracy and is superior in other

ways. We do not want 3-cup anemometers for accurate measuring instruments any more than we want 3-cylinder engines for our best automobiles, and for much the same reasons—inadequate, erratic, undependable starting and driving torque.

All the equations and numerical coefficients for the 4-cup standard rests upon a strong body of observational data comprising over 100 individual test points over a wide range of velocity. In contrast to this we have only 6 actual test values over a limited range of velocity on any 3-cup wheel whose dimensions are even approximately the same as those of the present standard. This is test wheel No. 30, point 9, and its position on the diagram

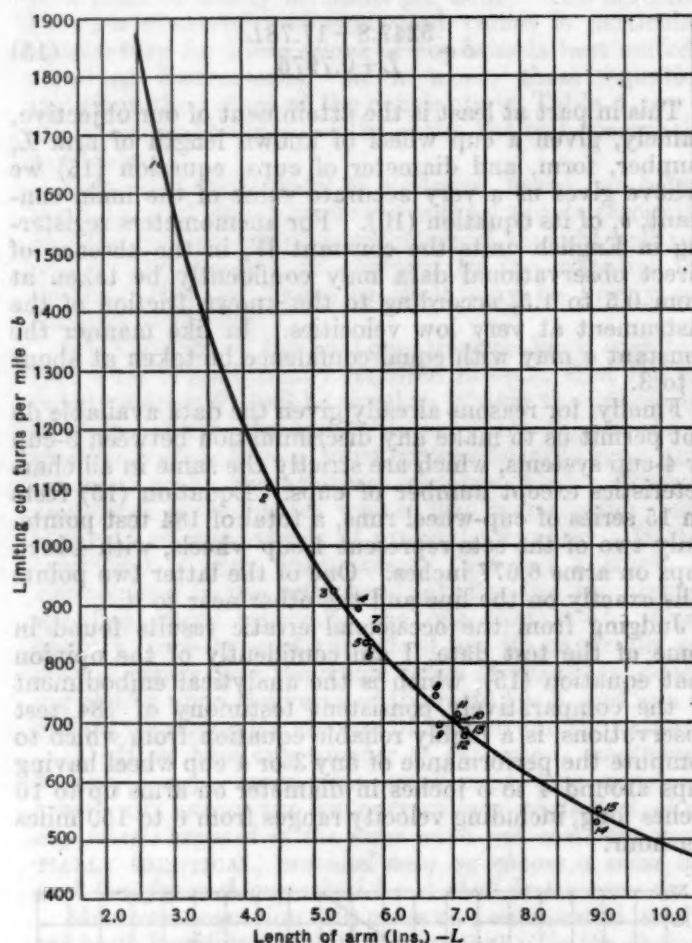


FIGURE 9.—Diagram showing the relation between the value of  $b$  in the hyperbolic equation and the length of arms of the anemometer cup wheel. Each observational point on the diagram represents the value of  $b$  in the equation for certain cup wheels represented by points Nos. 1 to 15, corresponding to the data under the same numbers given in Table 4, according to the length of cup-wheel arms.

Figure 9 is inconsistent with its companion 3-cup test data. A still more serious conflict arises with the tests made long after the wind tunnel tests were completed. These comprise a series of tests on two standard 3-cup wheels on two Friez magneto instruments, also over only a limited range of velocity. These indicate velocity directly on a voltmeter scale and completely lack any cup turn counting or integrating gear. Such instruments are about the worst type possible to subject to any accurate test, because values of  $N$ , the only fundamental datum we can measure, must be computed from eye readings, over a longer or shorter interval of time during a test, of the fluctuating position of the voltmeter needle, the scale for which is assumed to indicate miles per hour upon the inexact thesis that the cup wheels made 640 turns per

mile at all wind velocities, that the magnetos at all speeds generate 6 volts per 1,000 revolutions per minute, and that the voltmeter scale was itself correctly engraved on this basis.

Any student will recognize that these conditions constitute a serious handicap in executing basic tests on magneto anemometers. It is accordingly not surprising to find that values of  $b$  for the magnetos point No. 8 also fall well off the test data. In fact, if we take the simple mean value of the magneto and the No. 30 cup wheel tests we get a value for  $b$  which is almost exactly the same as that given for these anemometers by equation (15). That is, the general equation which agrees very well with the whole body of 3-cup test data gives us a better and more consistent value of  $b$  for the present standard 3-cup wheels than do the only sets of direct tests available themselves. Accordingly, we adopt the following equation for the new 3-cup wheel standard:

$$N = \frac{723.4 (W - 0.671)}{W + 2.0452} \quad (16)$$

This gives us the difference equation of errors:

$$V - W = \frac{0.13031 W - 2.5805}{1 + \frac{2.0452}{W}} \quad (17)$$

Contrasting this difference equation for the 3-cup standard with (14) for the 4-cup standard on the 3-cup spindle, we note that the coefficient of  $W$  in (17) is nearly twice as great as that for  $W$  in (14). This means that the errors of the 3-cup standard at high velocities are fully twice as large as for the 4-cup wheel when geared to 640 turns per mile registration. This is one among other good reasons why we advocate the superiority of the 4-cup standard.

*Another fallacy exposed.*—Disregarding more or less not only a rational conception of the performance of any cup wheel at very low and moderate velocities, but also the exactions of rigid definitions of  $F$  and  $N$ , including the equations of relations between them, a few writers, drawing hasty conclusions from observations mostly at relatively high velocities, are holding out the view that so-called compact cup wheels (big cups on short arms) are better for standard instruments than cup wheels of so-called slender proportions (length of arms 2 or 3 times cup diameter). In a word, the "factor" of the cup wheel of compact proportions is alleged to approach a "constant" value.

Recognizing that the body of observational data bearing upon this question is fragmentary and incomplete in important details, nevertheless I am convinced that this whole view is a misinterpretation of the evidence which when properly understood shows conclusively that for purposes of a high grade, infallible, standard anemometer for all-around station use, nearly or quite all the advantages go with 4-cup wheels of slender proportions.

In the first place, the usage of the concept "factors" by those advocating compact cup wheels is illogical and in conflict with definitions, observations, and rigid equations. The factor is always a variable with  $N$ . It is the product  $NF$  which is a rigorous constant, not  $F$  alone. Moreover, the ultimate result depends quite entirely upon the choice of the arbitrary number  $A$  and its ratio to the theoretical upper limit value of  $N$  which we call  $b$ , or if one pleases, to its "cousin" the reciprocal limiting value of  $F$  and the cup wheel dimensions. See equations (I) and (II).

The old 4-cup standard may be regarded as of slender proportions, and we have a large number of test observations thereon. With scarcely any exceptions these data are relatively self-consistent throughout and display a systematic relationship among themselves. In contrast to this the fragmentary and inadequate tests on the 3-cup systems, especially those of compact proportions are distinctly less self-consistent and in a few cases exhibit striking anomalies. Concerning these, and fully recognizing the paucity of observational proof, my thesis is that relatively compact cup wheels are wholly unfit for standard wind measuring instruments over a wide range of velocities.

Cup wheels of open dimensions and relatively long arms are uniform, systematic and dependable in their indications, simply because their angular velocity is relatively slow and deliberate. Both the slowly and the rapidly moving air streams *flow through* the whirling system with the minimum of vortical effects even at hurricane velocities, which must be reckoned with at times. The driving torques maintain a simple and systematic relationship with the wind travel. Quite the reverse is true in the case of cup wheels of compact dimensions. The angular velocity of these is necessarily very high, even with moderate wind speeds. The air stream *can not flow through* the rapidly whirling cup systems with sufficient freedom. Occasional observations seem to indicate that even at moderately brisk winds certain *critical aerodynamic states arise* under which a more or less stationary vortex of whirling air attaches itself to the whirling cups, whose angular velocity while this critical state exists is relatively erratic, anomalous and out of relation to angular velocities at both higher and lower wind speeds. In other words, the moving air stream does not flow uniformly *through*, but, at times at least, partially *around* these vortical whirls. Consequently, the driving torque in such cases is erratic and undependable.

Whether this thesis can ultimately be proven to be entirely sound or not must be left for future investigations. In the meantime, I must vigorously advocate the superiority of 4-cup wheels of open dimensions as the dependable standard for the Weather Bureau. The 4-cup systems are superior in point of mechanical symmetry, rigidity and strength of design, with no necessary sacrifice of lightness. Starting and driving torques are more dependable and uniform over the entire range of wind speeds commonly experienced anywhere.

#### CONCLUSIONS

(1) The new tests at the Bureau of Standards fully confirm the general high accuracy of the old tests on old 4-cup standard wheels, including the corrections for winds under 120 miles per hour by the old equation

$$\text{Log. } W = 0.509 + 0.9012 \frac{V}{3}$$

(2) The tests on the old 4-cup standard cup wheels constitute a strong body of observational data, and all

parties to the tests are in close accord as to the interpretation of these data and the performance of 4-cup wheels.

(3) While the data in Table 4 and their interpretation exhibited in Figure 9 seem to show that there is no striking systematic difference between the performance of otherwise exactly similar cup wheels, one having 3 cups, the other 4 cups, nevertheless a stronger body of observations on a more refined basis than now available is needed to bring out the small secondary differences which it is reasonable to believe must arise in the performance of cup wheels when the characteristics other than length of arm are changed. That is, the effect of changes in the form, diameter and number of cups, and in the friction of bearings on cup wheel performance can not be definitely evaluated, except from more numerous and better tests, especially on 3-cup wheels, than now available.

In the meantime, it is believed that equation (15) gives an entirely satisfactory working value to  $b$ , depending on the length of cup wheel arm for any anemometer of the type used in ordinary meteorological observations.

#### OFFICIAL ACTIONS OF THE WEATHER BUREAU BASED ON THE FOREGOING

(a) The old 4-cup standard was restored to use at approximately all stations of the Weather Bureau, beginning January 1, 1932, following an interval of five years from January 1, 1928, to December 31, 1931, during which the 3-cup anemometer was used generally as the Weather Bureau standard, on the assumption that the indicated velocities, based on 640 cup-wheel revolutions per mile of wind, were quite approximately true velocities.

(b) Complete confidence seems to be justified in the considerable accuracy of the new hyperbolic equations for representing the performance of 4 and 3 cup anemometers. These equations are:

For standard aluminum 4-cup wheels, 4-inch hemispherical cups on arms 6.68 inches.

$$V = \frac{\frac{686.41}{500} (W - .671)}{1 + \frac{1.314}{W}}$$

For the 5-inch 3-cup wheels on arms 6.29 inches,

$$V = \frac{\frac{723.4}{640} (W - .671)}{1 + \frac{2.045}{W}}$$

(c) In accordance with the foregoing, instructions were issued to all Weather Bureau stations to the effect that beginning with January 1, 1932, all values of wind velocity obtained from anemometers shall be corrected before being used for records, telegraphic reports, publications, or any other purpose, to the end that the best information available may be supplied to the public.

TABLE 1.—Original observations and derived data of anemometer tests in wind tunnel at Bureau of Standards.  $W$ =true velocity of wind,  $V$ =indicated velocity by the anemometer on the assumption that each cup wheel turn represented a fixed wind travel like 0.50, 0.75, 1.00, 2.00, 2.50 or 3.00 meters, according to an arbitrary factor  $F$  and actual length of arm  $L$ . Old standard 4-cup wheels.<sup>1</sup>

Date and run by serial number	Observed data, Velocities, m/sec.		Derived data		Specifications
	Wind, $W$	Anemometer indicated, $V$	Cup turns per mile $N$ $502.9V + W$	Factor $W + s$ $F = \frac{10084}{LN}$	
1922					
Mar. 31, No. 1.	6.8	7.9	584	2.69	Nominal aluminum 4-cup wheel standard No. 1. All 4-cup wheels in Table 1 have 4-inch cups on square steel arms, set edgewise to the wind. Diameter 5/32-inch, length averaging close to 6.67 inches. Spindle with plain bearing. Low speed tunnel 4.0 feet diameter.
	10.1	12.0	598	2.53	
	15.2	19.0	629	2.40	
	20.3	25.9	642	2.36	
	25.4	32.7	647	2.34	
	30.5	39.5	651	2.32	
	35.6	46.7	656	2.30	
	38.6	50.5	658	2.30	
Mar. 31, No. 2.	6.9	7.9	576	2.62	Same conditions as in above run.
	10.2	12.0	592	2.55	
	15.3	19.1	628	2.41	
	20.4	26.0	641	2.36	
	25.5	33.0	651	2.32	
	30.6	39.4	648	2.33	
	35.7	47.0	662	2.28	
	38.8	50.9	660	2.29	
Mar. 31, No. 4.	7.4	8.4	568	2.66	Same conditions as in preceding, except ball bearings at top of spindle.
	10.2	12.2	602	2.51	
	15.4	19.2	627	2.41	
	20.5	26.2	643	2.35	
	25.6	33.2	652	2.32	
	30.7	40.0	655	2.31	
	35.6	47.1	662	2.28	
	38.9	51.1	661	2.29	
Mar. 31, No. 5.	7.2	8.0	550	2.70	Same conditions as in preceding run except plain bearings instead of ball bearings.
	10.2	12.0	592	2.55	
	15.3	19.1	628	2.41	
	20.4	25.6	631	2.40	
	25.5	32.8	647	2.34	
	30.6	39.8	654	2.31	
	35.7	47.0	662	2.28	
	38.7	51.0	663	2.28	
Apr. 8, No. 27.	4.3	4.4	515	2.94	Same as in preceding run with cup wheel No. 1, except high speed tunnel, 3 feet diameter.
	9.3	10.3	557	2.71	
	19.0	23.6	625	2.42	
	28.8	37.3	652	2.32	
	38.4	50.6	662	2.28	
Apr. 8, No. 31.	5.2	5.2	503	3.00	Duplicate of preceding run.
	9.3	10.4	562	2.69	
	19.3	23.6	625	2.42	
	28.8	37.2	650	2.33	
	38.4	50.5	661	2.29	
	50.7	66.7	682	2.28	
	60.8	80.8	688	2.26	
July 21, No. 40.	6.7	7.2	541	2.79	Cup wheel No. 1, same as in preceding, with plain bearings and low speed tunnel.
	10.2	11.8	582	2.60	
	15.3	19.1	628	2.41	
	25.5	32.8	649	2.33	
	38.7	49.6	644	2.35	
Apr. 8, No. 28.	5.4	5.0	466	3.24	Aluminum cup wheel No. 2, practically a duplicate of cup wheel No. 1, tested in high speed tunnel, with plain bearings.
	9.2	10.4	568	2.66	
	18.9	24.0	638	2.37	
	28.7	37.4	656	2.30	
	38.4	51.0	668	2.26	

<sup>1</sup> The old standard 4-cup wheels were supposed to have arms of the nominal length of 6.72 inches. On the basis of a factor 3.00 such cup wheels would make 500 turns per mile of wind travel. A special gearing was devised for these tests in order that the electrical registrations should show indicated velocities,  $V$ , directly in approximate meters per second. This gearing introduced an error of 0.06 per cent. The true value of indicated velocity is, therefore, 0.06 per cent greater than  $V$  as tabulated.

TABLE 1.—Original observations and derived data of anemometer tests in wind tunnel at Bureau of Standards.  $W$ =true velocity of wind,  $V$ =indicated velocity by the anemometer on the assumption that each cup wheel turn represented a fixed wind travel like 0.50, 0.75, 1.00, 2.00, 2.50 or 3.00 meters, according to an arbitrary factor  $F$  and actual length of arm  $L$ . Old standard 4-cup wheels.—Continued

Date and run by serial number	Observed data, Velocities, m/sec.		Derived data		Specifications
	Wind, $W$	Anemometer indicated, $V$	Cup turns per mile $N$ $502.9V + W$	Factor $W + s$ $F = \frac{10084}{LN}$	
1922					
Apr. 21, No. 45.	5.4	5.7	531	2.85	Aluminum cup wheel No. 5, essentially like Nos. 1 and 2, except arms are round, plain bearings, and high-speed tunnel.
	10.0	11.0	583	2.73	
	15.0	18.4	617	2.45	
	20.2	25.5	635	2.38	
	30.2	39.4	656	2.30	
	40.4	53.2	662	2.28	
Apr. 21, No. 46.	6.1	6.1	503	3.01	Round arm, aluminum cup wheel No. 6, practically duplicate of No. 5. Test also in high-speed tunnel; plain bearings.
	10.0	11.7	588	2.57	
	15.0	18.6	624	2.42	
	20.2	25.6	637	2.37	
	30.2	39.6	659	2.29	
	41.0	63.9	661	2.29	
	50.4	67.5	674	2.24	
	60.5	79.6	663	2.28	
Mar. 31, No. 3.	7.3	7.9	524	2.88	Copper cup wheel No. 3 on square arms, otherwise similar to No. 1, except arms have flat metal braces edgewise to wind. Low-speed tunnel; plain bearings. Cup wheel found out of balance.
	10.2	12.1	597	2.53	
	15.4	18.6	607	2.49	
	20.5	25.4	623	2.43	
	25.6	32.1	631	2.40	
	30.7	39.4	645	2.34	
	35.8	46.4	652	2.32	
	38.9	50.6	654	2.31	
Mar. 31, No. 6.	7.3	8.0	551	2.74	Duplicate test of cup wheel No. 3 after wheel was balanced.
	10.2	11.5	567	2.67	
	15.3	18.4	605	2.50	
	20.4	25.2	621	2.43	
	25.5	32.2	636	2.38	
	30.6	39.0	641	2.36	
	35.7	46.0	648	2.33	
	38.8	49.9	647	2.34	
Apr. 8, No. 32.	6.4	6.6	519	2.91	Cup wheel No. 3 as balanced in ball bearings. Tested in high-speed tunnel.
	9.2	9.8	536	2.82	
	18.9	22.6	602	2.51	
	28.8	36.3	634	2.38	
	38.5	49.6	648	2.33	
	50.8	66.0	654	2.31	
	60.9	79.5	656	2.30	
Apr. 8, No. 29.	6.1	6.2	512	2.95	Cup wheel No. 3 as before in plain bearings, high-speed tunnel.
	9.2	9.8	536	2.82	
	18.8	22.6	604	2.50	
	28.7	36.6	640	2.36	
	38.3	49.4	649	2.33	
Apr. 8, No. 30.	6.1	6.2	511	2.96	Copper cup wheel No. 4, similar to No. 3. Tested in high-speed tunnel. Plain bearings.
	9.2	9.9	541	2.79	
	18.9	23.0	612	2.47	
	28.7	36.6	642	2.35	
	38.4	49.8	652	2.32	
Apr. 8, No. 33.	6.2	6.8	552	2.74	Heavy seacoast copper cup wheel No. 7. Cups on heavy square steel arms with flat braces broadside to the wind, large plain bearings. Test in high-speed tunnel. The great difference between this test and those of other like 4-cup wheels is not explainable.
	9.2	10.2	558	2.71	
	18.9	22.0	586	2.58	
	28.8	34.0	594	2.54	
	38.4	45.5	596	2.54	
	50.7	61.2	607	2.49	
	60.8	73.8	611	2.47	

TABLE 2.—Original observations and derived data of anemometer tests in wind tunnel at Bureau of Standards.  $W$ =true velocity of wind,  $V$ =indicated velocity by the anemometer on the assumption that each cup wheel turn represented a fixed wind travel,  $P=0.50$ , 0.75, 1.00, 2.00, 2.50, or 3.00 meters, according to an arbitrary factor  $F$  and actual length of arm  $L$ . Miscellaneous 3-cup wheels of various dimensions.

Date and run by serial number	Observed data Velocities m/sec.		Derived data		Specifications
	Wind, $W$	Anemometer indicated, $V$	Cup turns per mile $N = \frac{V}{P}$	Factor $F = \frac{W}{V}$	
1922					
July 21, No. 56.	7.1	6.3	2856	3.07	Cup wheel No. 15: $d$ =cup diameter=1.57 inches. $L$ =length of arm=1.15 inches. $P$ =assumed travel per turn=0.5 meters. Ball bearing spindle. Low-speed tunnel.
	10.3	9.4	2937	2.99	
	15.4	14.0	2926	3.00	
	20.6	19.2	3000	2.92	
	30.9	29.0	3021	2.90	
	39.2	36.2	2972	2.95	
July 21, No. 57.	7.3	6.8	1999	2.85	Cup wheel No. 16: $d$ =1.57 inches. $L$ =1.77 inches. $P$ =0.75 meters. Ball bearing spindle. Low-speed tunnel.
	10.7	10.2	2045	2.79	
	15.5	15.3	2188	2.69	
	20.7	20.8	2186	2.64	
	31.0	31.5	2180	2.61	
	38.3	39.4	2207	2.58	
July 21, No. 58.	7.1	6.2	1405	3.04	Cup wheel No. 17: $d$ =1.57 inches. $L$ =2.36 inches. $P$ =1 meter. Ball bearing spindle. Low-speed tunnel.
	10.3	9.5	1484	2.88	
	15.4	14.8	1547	2.76	
	20.6	20.2	1578	2.71	
	30.9	31.5	1641	2.30	
	39.2	39.6	1626	2.03	
July 21, No. 57.	7.3	6.4	1411	3.03	Cup wheel No. 15 tested simultaneously during this run.
	10.7	6.9	1489	2.87	
	15.5	14.9	1547	2.76	
	20.7	20.8	1618	2.64	
	31.0	32.2	1672	2.60	
	38.3	40.1	1685	2.54	
July 21, No. 59.	6.7	6.8	1633	2.64	Cup wheel No. 18: $d$ =4 inches. $L$ =2.34 inches. $P$ =1 meter. Ball bearing spindle. Low-speed tunnel.
	10.2	10.1	1594	2.70	
	15.3	15.6	1641	2.63	
	20.4	20.6	1625	2.65	
	30.7	31.3	1641	2.63	
	37.8	38.6	1643	2.62	
Apr. 21, No. 47.	5.6	5.4	776	2.72	Cup wheel No. 19: $d$ =4 inches. $L$ =4.78 inches. $P$ =2 meters. Ball bearing spindle. High-speed tunnel.
	10.0	10.2	821	2.57	
	15.0	15.8	848	2.49	
	20.2	21.5	856	2.46	
	30.3	33.1	879	2.40	
	40.4	44.4	884	2.39	
Apr. 21, No. 48.	6.1	6.0	792	2.66	Cup wheel No. 20: Duplicate of No. 19. Ball bearing spindle. High-speed tunnel.
	10.0	10.4	837	2.52	
	15.1	16.0	853	2.47	
	20.2	21.8	868	2.43	
	30.3	33.9	900	2.34	
	40.4	45.9	914	2.31	
	50.6	57.2	*909	2.32	
	60.7	67.0	*888	2.38	
July 21, No. 51.	7.1	6.4	726	2.61	Cup wheel No. 21: $d$ =4 inch. $L$ =5.33 inches. $P$ =2 meters. Ball bearing spindle. Low-speed tunnel.
	10.3	9.4	734	2.58	
	15.4	14.6	762	2.48	
	20.4	19.8	769	2.46	
	30.7	30.5	800	2.36	
	37.8	38.0	809	2.34	
July 21, No. 53.	7.2	6.4	715	2.61	Cup wheel No. 25: $d$ =4.5 inches. $L$ =5.4 inches. $P$ =2 meters. Ball-bearing spindle. Low-speed tunnel.
	10.5	9.7	743	2.51	
	15.4	15.1	789	2.55	
	20.5	20.5	805	2.32	
	30.8	31.4	820	2.28	
	37.9	38.9	826	2.26	
1923					
July 6, No. 60.	6.9	6.2	723	2.71	Cup wheel No. 23: $d$ =5 inches. $L$ =5.14 inches. $P$ =2 meters. Ball-bearing spindle. Low-speed tunnel.
	10.1	9.9	759	2.49	
	15.0	15.1	826	2.38	
	20.0	20.7	833	2.36	
	30.0	31.8	853	2.30	
July 6, No. 61.	6.7	6.3	757	2.54	Cup wheel No. 31: $d$ =6 inches. $L$ =5.24 inches. $P$ =2 meters. Ball-bearing spindle. Low-speed tunnel.
	10.0	9.4	760	2.54	
	15.4	14.8	798	2.43	
	20.0	19.7	793	2.43	
	30.0	30.4	815	2.36	
July 6, No. 58.	6.9	6.4	597	2.58	Cup wheel No. 26: $d$ =4.5 inches. $L$ =5.55 inches. $P$ =2.5 meters. Ball-bearing spindle. Arms 11 mm in diameter. Low-speed tunnel.
	6.5	5.8	574	2.68	
	9.8	9.4	617	2.50	
	15.0	14.7	631	2.44	
	20.0	20.1	647	2.38	
	30.1	31.2	669	2.30	
	35.0	36.8	677	2.27	
July 6, No. 59.	6.8	6.3	596	2.58	Cup wheel No. 26: Arms reduced to 5.6 mm diameter. Ball-bearing spindle. Low-speed tunnel.
	10.0	9.6	618	2.49	
	15.0	15.2	652	2.36	
	20.0	20.8	670	2.30	
	30.0	32.0	686	2.24	

TABLE 2.—Original observations and derived data of anemometer tests in wind tunnel at Bureau of Standards.  $W$ =true velocity of wind,  $V$ =indicated velocity by the anemometer on the assumption that each cup wheel turn represented a fixed wind travel,  $P=0.50$ , 0.75, 1.00, 2.00, 2.50, or 3.00 meters, according to an arbitrary factor  $F$  and actual length of arm  $L$ . Miscellaneous 3-cup wheels of various dimensions—Continued.

Date and run by serial number	Observed data Velocities m/sec.		Derived data		Specifications
	Wind, $W$	Anemometer indicated, $V$	Cup turns per mile $N = \frac{V}{P}$	Factor $F = \frac{W}{V}$	
1923					
July 6, No. 63.	6.7	6.0	577	2.78	Cup wheel No. 30: $d$ =5 inches. $L$ =6.29 inches. $P$ =2.5 meters. Ball-bearing spindle. Low-speed tunnel.
	10.2	9.8	619	2.69	
	15.0	15.0	644	2.49	
	20.0	20.6	663	2.42	
	30.0	31.0	665	2.41	
	35.0	36.6	674	2.38	
July 6, No. 62.	6.8	6.3	596	2.58	Cup wheel No. 32: $d$ =6 inches. $L$ =6.56 inches. $P$ =2.5 meters. Ball-bearing spindle. Low-speed tunnel.
	10.1	10.2	650	2.36	
	15.0	15.2	652	2.36	
	20.0	21.0	670	2.27	
	30.0	31.9	685	2.24	
1922					
July 21, No. 62.	6.9	5.7	443	2.65	Cup wheel No. 22: $d$ =4 inches. $L$ =8.59 inches. $P$ =3 meters. Ball-bearing spindle.
	10.3	8.7	483	2.59	
	15.3	14.0	491	2.39	
	20.4	19.2	505	2.32	
	30.6	29.7	521	2.25	
July 21, No. 54.	37.3	36.9	531	2.21	Low-speed tunnel.
	7.3	6.0	441	2.66	Cup wheel No. 27: $d$ =4.5 inches. $L$ =8.59 inches. $P$ =3 meters. Ball-bearing spindle. Low-speed tunnel.
	10.5	9.0	465	2.51	
	15.4	14.2	495	2.38	
	20.5	19.4	508	2.31	
	30.8	29.8	519	2.27	
	38.0	37.4	528	2.22	
July 21, No. 55.	6.9	6.2	482	2.44	Heavy brass cup wheel No. 33: $d$ =6.11 inches. $L$ =8.59 inches. $P$ =3 meters. Ball-bearing spindle. Low-speed tunnel.
	10.3	9.5	495	2.38	
	15.4	14.8	510	2.28	
	20.6	19.8	516	2.28	
	25.7	24.7	516	2.28	

TABLE 3.—Tests of 2 Friez magneto anemometers equipped with standard 3-cup wheels. Run 64, magneto built without wind vane; run 65, another magneto with wind vane; run 66, same magneto with vane removed. Indicated velocities read from voltmeter scale graduated directly in miles per hour.

Date and run	Observed data Velocity m/hr.		Derived data		Specifications
	Wind, $W$	Voltmeter velocity $V$	Cup turns per mile $N = \frac{640V}{P}$	Factor $F = \frac{W}{V}$	
1929					
June 7, No. 64.	12.6	12.6	640	2.52	Standard 3-cup wheel: $d$ =5.02 inches. $L$ =6.254 inches. $P$ =2.5 meters.
	13.6	13.3	626	2.58	
	23.6	23.7	643	2.51	
	28.9	29.6	656	2.46	
	33.6	34.8	603	2.43	
	41.0	43.3	676	2.39	
	45.6	49.2	691	2.33	
	45.8	48.2	673	2.40	
	51.9	56.0	690	2.34	
	57.4	62.3	695	2.32	
	62.6	70.3	716	2.25	
	69.2	75.7	698	2.31	
	61.0	66.8	701	2.30	
	50.2	54.0	688	2.34	
	44.9	48.5	691	2.33	
	40.7	42.6	670	2.40	
	37.5	37.7	645	2.50	
	12.6	12.5	635	2.54	

To secure  $N$  accurately in any test requires that the instruments be provided with some form of worm wheel counting and registration gear. Without this integrating mechanism in the present case,  $N$  could be computed only approximately from eye readings of the slightly oscillating needle of the voltmeter, which indicated only the momentary angular cup velocities converted into miles per hour, upon the inexact assumption that the cup wheels made 640 turns per mile of wind travel, that the magneto generates 6 volts per 1,000 revolutions per minute, and that the voltmeter is correctly scaled to miles per hour on this basis. The scattered distribution of these observations, as plotted in figure, indicates the inexactitude of the results as a whole. Certain corrections are recognized as being required, but these are not sufficiently known to justify application.

TABLE 3.—Tests of 2 Friez magneto anemometers equipped with standard 3-cup wheels. Run 64, magneto built without wind vane; run 65, another magneto with wind vane; run 66, same magneto with vane removed. Indicated velocities read from voltmeter scale graduated directly in miles per hour—Continued

Date and run	Observed data. Velocity m/hr.		Derived data		Specifications
	Wind, W'	Volt- meter velocity V	Cup turns per mile, $N = \frac{640V}{W}$ approximate	Factor $W = \frac{640V}{N}$ $F = \frac{10084}{LN}$	
1929 June 7, No. 65.	12.6	12.7	646	2.50	Standard 3-cup wheel: Similar magneto, but equipped with wind vane. $d = 5.03$ inches. $L = 6.244$ inches. $P = 2.5$ meters. Large tunnel, open air.
	19.2	20.0	667	2.42	
	24.9	25.0	648	2.51	
	31.1	32.3	665	2.43	
	35.5	38.3	690	2.34	
	42.8	45.4	679	2.38	
	45.7	50.0	700	2.31	
	52.4	56.8	694	2.31	
	56.8	63.5	715	2.26	
	57.8	64.0	720	2.24	
	64.6	71.5	708	2.28	
	69.6	77.0	708	2.28	
	59.0	65.3	708	2.28	
	46.5	50.7	698	2.31	
	31.9	33.4	670	2.41	
	20.3	20.3	631	2.56	
June 7, No. 66.	14.1	13.0	590	2.74	Same cup wheel and magneto, with vane removed, necessitating an im- proved substitute for ball bearing. Large tunnel, open air.
	21.8	21.4	628	2.57	
	26.0	26.7	657	2.49	
	31.7	33.2	670	2.41	
	39.2	41.5	678	2.38	
	46.3	50.4	697	2.32	
	49.2	54.3	706	2.29	
	55.9	61.5	704	2.29	
	60.5	66.5	703	2.30	
	65.4	72.2	707	2.28	
	70.6	78.3	710	2.27	

TABLE 4.—Data and constants for hyperbolic equations, asymptotes parallel to coordinate axes, giving the relations between  $N$ , number of turns per mile of wind velocity, and  $W$ , the wind velocity in meters per second

$$\text{Equation, } N = \frac{b(W - W_0)}{W + a}$$

Case	Cup wheel			Max. N b	Curva- ture a	Friction W <sub>0</sub>	Remarks
	No.	Arms L	Cups diam- eter, d				
		Inches	Inches				
1.....	18	2.34	4.0	1,650.0	-0.113	0.30	Shortest arms for 4-inch cups.
2.....	34	3.81	4.5	1,100.0	.002	.67	Two 1/2000-mile wheels tested on Friez no vane magneto.
	35	3.92	5.0	922.5	.847	.30	Duplicate wheels; 2 runs.
3.....	19	4.78	4.0				
	20	4.78	4.0	893.1	1.064	.30	Single run on 1 wheel.
4.....	28	5.14	5.0				
5.....	31	5.24	6.0	835.2	.548	.30	Do.
6.....	21	5.33	4.0	834.5	1.040	.30	Do.
7.....	25	5.40	4.5	857.7	1.013	.30	Do.
8.....		6.25	5.02	745.4	.909	.67	2 standard 3-cup wheels tested on 2 Friez magnetos.
		6.24	5.03	696.6	.919	.30	Only 3-cup wheel close to standard tested in tunnel, velocity range 7 to 35 m/sec.
9.....	30	6.29	5.0				
10.....	26	6.55	4.5	704.8	1.030	.30	3-cup wheel, thick arms; 3-cup wheel arms thinner.
11.....	32	6.56	6.0	711.6	.841	.30	Nos. 8, 9, 10, 11 nearly like 3-cup standard.
12.....		6.677	4.0	686.4	1.313	.30	Mean of 68 tests on aluminum 4-cup wheels over maximum range of velocity 4-61, m/sec.
13.....		6.677	4.0	678.2	1.582	.30	Mean of 33 tests to highest velocity of copper 4-cup wheels.
14.....	33	8.56	6.11	530.1	.093	.50	Heavy brass cup, long arms.
15.....	22	8.59	4.0	551.0	1.527	.30	2 long arm cup wheels.
	27	8.59	4.5				

NOTE.—Nos. 12 and 13 in this table relate to the large number of tests on the 4-cup anemometers. A few of these tests were carried to the extreme velocity of 60 meters per second. All the remaining cases represent often only a single run on 3-cup wheels, and of these only 8, 9, 10, and 11 represent anemometers which are fairly comparable, not identical, with the present 3-cup standard. Only in case 3, duplicate cup wheels 19 and 20, did the velocity exceed 35 meters per second, and in this case the cups were deformed above 40 meters per second, leaving the performance of the 3-cup wheels at high velocities in doubt.

## WET-BULB DEPRESSION AS A CRITERION OF FOREST-FIRE HAZARD

By J. R. LLOYD

[Weather Bureau, Chicago, Ill., March 10, 1932]

Ever since the inauguration of the fire-weather work by the Weather Bureau in the forested areas of this country there has been a need for a convenient scale or formula for use in estimating the combined effects of temperature and relative humidity on forest-fire hazard. It has been known for a long time that both temperature and relative humidity exert an influence on fire hazard. However, these two elements are so associated that it is very difficult to assign proper values to each. The writer has for several years been engaged on fire-weather work in the upper Great Lakes region, and therefore has more than an ordinary interest in this problem. If a single scale or formula could be found that would measure the combined effects of temperature and relative humidity on forest-fire hazard to a reasonable degree of accuracy it would go a long way in solving one of the most difficult problems in fire-weather work.

In order to start on this problem it was necessary to gather a lot of data on forest fires. The writer chose the season of 1930 for fire data because of the fact that most of the season was bad from a hazard standpoint. Fire report cards were sent to the district forest rangers, who reported on about 5,000 separate fires that occurred in Wisconsin and Michigan during 1930. One report card was used for each fire, on which was shown the time of beginning and of ending of the fire, the area burned, the type of forest cover burned, and the kind of soil, in general, that was burned over. With this information at hand and with the weather data that had been collected from

several fire-weather stations in the forested area, it was possible to attack the problem from several angles, if necessary.

It was decided to chart each fire against the temperature and relative humidity that prevailed at the time the fire broke out. The accompanying chart, Figure 1, shows the manner in which this was done, except the chart as originally prepared showed in colors the sizes of the fires according to several different size classifications, which can not be shown on the chart herewith. Only the fire reports from the districts that had weather observing stations and reliable records were used. By way of explanation of the chart, it should be said that each dot represents a fire, and that the position of each dot on the chart indicates the temperature and the relative humidity that prevailed shortly before the fire was first noticed by the forest guard. It should be noted that each degree of temperature is represented by a band 5 millimeters wide running vertically on the chart, and each 1 per cent of relative humidity by a 5 millimeter band running horizontally across the chart. The fires are charted in the 5-millimeter squares at the intersections of these bands that represent temperature and relative humidity. It may be seen that in some of the 5-millimeter squares as many as eight fires have been charted. A total of 3,002 fires were charted.

When the chart is examined carefully it will be found that it presents some very interesting features. Probably the most outstanding feature is the heavy preponderance

of fires that broke out with temperature above 70° and relative humidity below 45 per cent. This indicates that the greatest danger of fire inception lies in that sector of the chart. Part of this heavy preponderance is, no doubt, due to the fact that more chances occur for fires to break out during the run of a season with temperatures

manner in which the fires are charted, to show just how much more chance there is for fires to break out under the former named conditions than under the latter. However, it is known from experience in dealing with the problem from day to day that only a part of the preponderance as shown on the chart is caused by more

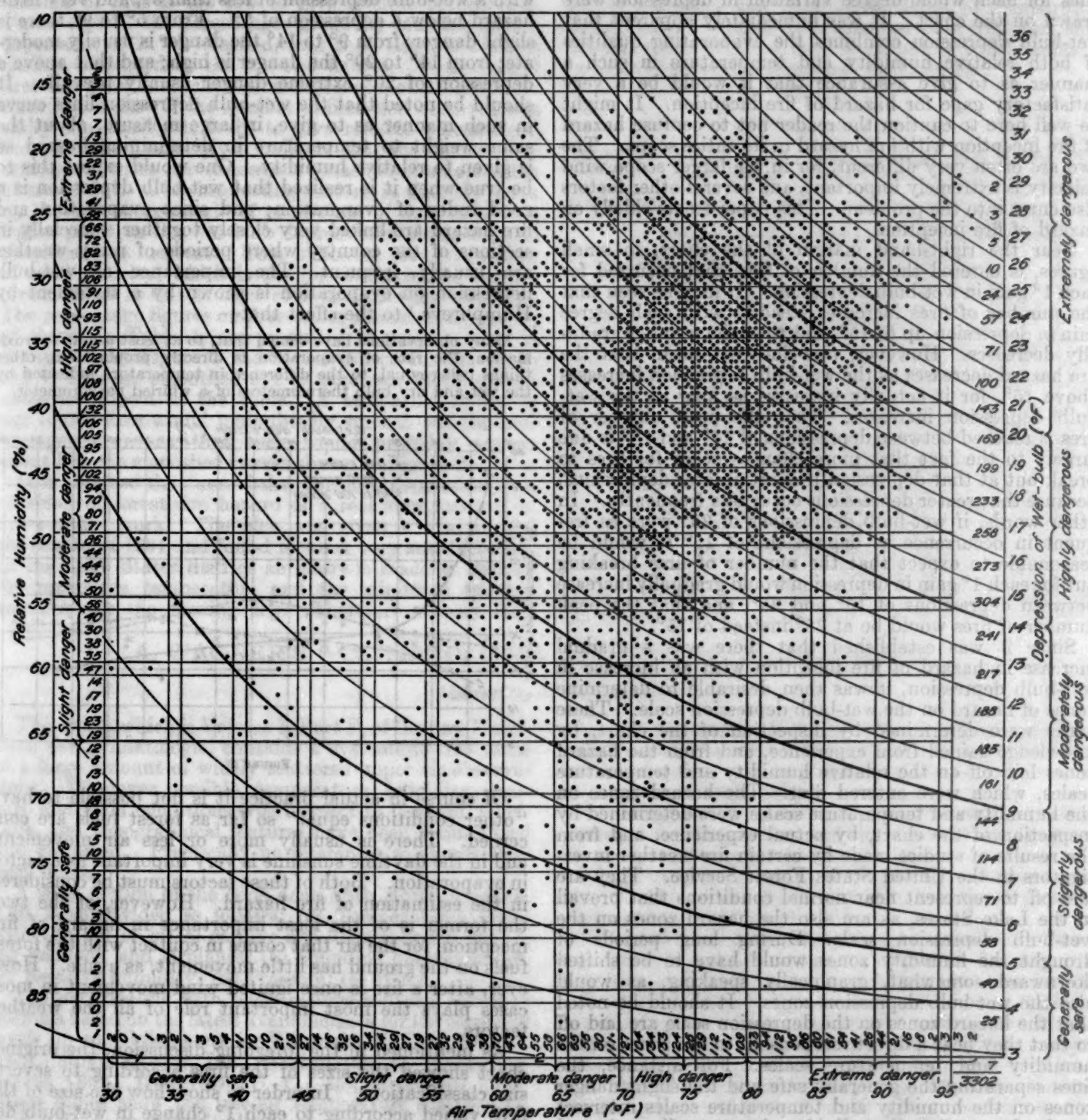


FIGURE 1

between 70° and 90° and relative humidity between 45 per cent and 25 per cent than at other temperatures and humidities, because those temperatures and humidities probably occur more frequently during the fire season than do other temperatures and humidities. It would be extremely difficult, in fact impossible, considering the

frequent occurrence of weather conditions in that sector of the chart that would cause fires, and that probably only a rather small part of the preponderance is due to that feature.

As the principal reason for charting the fires in the manner shown was to determine some method of estimat-

ing accurately to a reasonable degree the combined effects of temperature and relative humidity on fire hazard, it appeared that the wet-bulb depression might prove to be the most satisfactory agent. Accordingly, the wet-bulb depression values were computed for the various combinations of temperature and relative humidity, and lines for each whole degree variation in depression were drawn on the chart. It was immediately apparent that wet-bulb depression combines the evaporating qualities of both relative humidity and temperature in such a manner as to give assurance that it would be a very satisfactory gage for hazard of fire inception. It might be well here to caution the reader not to confuse hazard of fire inception with fire hazard in its entire scope. The two are often very different, for in the larger scope wind velocity is extremely important, and several other factors also enter into the problem. This paper treats chiefly on hazard of fire inception.

Near the right-hand margin of the chart, in small figures, is entered the number of fires that occurred for each 1° gain in wet-bulb depression. It may be seen that the number of fires increases steadily with each degree gain in depression up to 15°, and then the number gradually decreases. However, this does not mean that the fire hazard decreases as the wet-bulb depression increases above 15°, for it actually increases as long as the wet-bulb depression increases. That the peak number of fires is reached between depressions of 14° and 15° is due largely to the fact that more chances occur for fires to break out at that depression than at greater depressions, because the greater depressions occur less frequently. In other words, if wet-bulb depressions of 25° were as frequent in occurrence as depressions of 15° it would be reasonable to expect that the number of fires breaking out for each 1° gain in depression would gradually increase between depressions of 15° and 25°, and that the peak number of fires would be at 25° instead of 15°.

Since it was established that there was a gradual increase in hazard of fire inception with an increase in wet-bulb depression, it was then desirable to determine zones of hazard on the wet-bulb depression scale. These zones were determined by inspection of the chart, by knowledge gained from experience, and from the hazard zones laid off on the relative humidity and temperature scales, which were entered first. The hazard zones on the humidity and temperature scales were determined by inspection of the chart, by actual experience, and from the results of studies made by certain fire-weather investigators in the United States Forest Service. They are laid off to represent near normal conditions that prevail in the Lake States, as are also the hazard zones on the wet-bulb depression scale. During long periods of drought the humidity zones would have to be shifted downward somewhat, graphically speaking, as would also the wet-bulb depression zones. It should be noted that the hazard zones on the depression scale are laid off so that they bear a direct relationship to the zones on the humidity and temperature scales. For instance, the lines separating the generally safe and the slight danger zones on the humidity and temperature scales intersect on the heavy line that divides the generally safe and slightly dangerous zones on the depression scale. Likewise the dividing lines between the slight and moderate danger zones and the moderate and high danger zones on the humidity and temperature scales intersect on or near the dividing lines between the slight and moderate danger zones and the moderate and high danger zones on the depression scale. The heavy line dividing the high and

extreme danger zones on the depression scale was moved down a degree from the intersection point of the dividing lines for the same temperature and humidity zones, because it was felt that in this case the intersection point fell a little too high on the scale.

It is obvious from the chart that there is no fire hazard with a wet-bulb depression of less than 3°, and very little hazard below a depression of 5°. From 5° to 9° there is slight danger; from 9° to 14° the danger is usually moderate; from 14° to 20° the danger is high; and that above a depression of 20° extreme danger usually prevails. It should be noted that the wet-bulb depression lines curve in such manner as to give, in large measure, about the same weight to temperature in determining hazard as is given to relative humidity. One would expect this to be true when it is realized that wet-bulb depression is a good index of evaporation; and since evaporation and fire hazard are linked very closely together, especially in sections of the country where periods of rainy weather are usually frequent. The importance of wet-bulb depression on evaporation is shown by a statement by Humphreys<sup>1</sup> to the effect that—

Many observations have shown that, to at least a first approximation, the rate of evaporation is directly proportional, other things being equal, to the difference in temperature indicated by the wet and dry bulb thermometers of a whirled psychrometer.

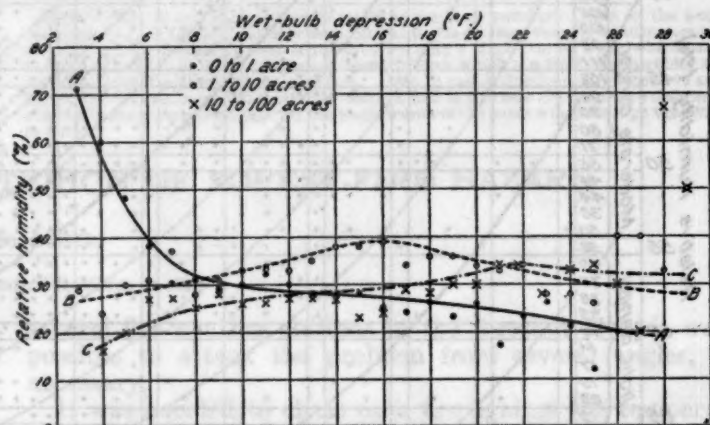


FIGURE 2

Of course in actual practice it is not possible to have "other conditions equal" so far as forest fuels are concerned. There is usually more or less air movement, and in the daytime sunshine is very important as a factor in evaporation. Both of these factors must be considered in the estimation of fire hazard. However, of the two, the former is of the least importance in hazard of fire inception, for the air that comes in contact with the forest fuels on the ground has little movement, as a rule. However, after a fire is once ignited wind movement in most cases plays the most important rôle of all the weather factors.

As mentioned in the foregoing discussion, the original chart showed the sizes of the fires according to several size classifications. In order to show how the size of the fires varied according to each 1° change in wet-bulb depression a tabulation was made as shown in Table 1. In this tabulation the number of fires that occurred at each degree of depression is shown for each size classification, and the per cent that each number is of the total number of fires for each degree in depression is also given. These percentages are interesting. The figures on the class A

<sup>1</sup> W. J. Humphreys, *Physics of the Air*, p. 247.

fires show that the percentages decrease from the beginning as the wet-bulb depression rises. This is exactly what would be expected. With the class B fires the percentages rise gradually as the depression rises until a depression of  $16^{\circ}$  is reached, and then there is a gradual decline, except at depressions above  $25^{\circ}$ , where the number of fires is too few to give reliable percentages. Under class C the percentages gradually increase until a depression of  $21^{\circ}$  is reached, and then there is a slight decline, disregarding the last two figures. With class D fires the peak is reached at a depression of  $23^{\circ}$ . Under class E and class F the number of fires that occurred was really too small relatively to give reliable percentages; however, the figures given indicate that the highest percentages in these two classes were reached at a depression of about  $25^{\circ}$ . The interesting feature is that the peak on the percentage scale of each class of fires falls at a higher point on the wet-bulb depression scale as the size classifications increase. This indicates that, regardless of wind velocity, which is the big factor in fire spread, fires increase in size as the wet-bulb depression increases. The percentage figures on fires under classes A, B, and C, as shown in Table 1, are presented in graphic form in Figure 2. In Figure 2 the curves drawn for the A, B, and C fires are smoothed out to take care of the inconsistencies shown in the table. A tabulation of let us say 10,000 fires would undoubtedly smooth out the percentage curves so that they would probably appear about like the smoothed curves shown in Figure 2.

It is believed that use of the wet-bulb depression as a criterion of forest fire hazard is a real step forward in fire-weather work. The idea was given a trial during the season of 1931 and found to work very satisfactorily. In the Lake States district an effort is made to predict the maximum temperature and the minimum relative humidity for the ensuing day. Therefore a chart such

as the one shown here should be valuable aid to the forest ranger as well as to the meteorologist, for it enables one to assign about the proper weight to both the temperature and the relative humidity that is expected, or that may be prevailing, in estimating the hazard. In working out the wet-bulb depression idea other methods for determining the combined effects of temperature and relative humidity on fire hazard were tried and eliminated, either because they were not of much value or because they were impractical for daily use.

TABLE 1

Wet-bulb depression	A 0 to 1 acre		B 2 to 10 acres		C 11 to 100 acres		D 101 to 500 acres		E 501 to 1,000 acres		F 1,000 acres and over		Total number of fires
	Fires	Per cent	Fires	Per cent	Fires	Per cent	Fires	Per cent	Fires	Per cent	Fires	Per cent	
3.....	5	71	2	29	0	0	0	0	0	0	0	0	7
4.....	15	60	6	24	4	16	0	0	0	0	0	0	25
5.....	19	48	12	30	8	20	1	2	0	0	0	0	40
6.....	22	38	18	31	16	27	1	2	1	2	0	0	58
7.....	21	30	26	37	19	27	9	4	1	1	1	1	71
8.....	37	31	32	28	28	25	11	10	3	3	3	3	114
9.....	42	29	44	31	40	29	13	9	2	1	2	2	144
10.....	48	30	53	33	42	26	14	9	2	1	2	1	161
11.....	60	32	61	33	48	26	12	7	2	1	2	1	186
12.....	67	30	63	33	50	27	13	7	4	2	1	1	188
13.....	60	28	76	35	58	27	16	7	5	2	2	1	217
14.....	68	28	91	38	64	27	10	4	2	1	6	2	241
15.....	85	28	117	38	70	23	18	6	6	2	3	3	304
16.....	68	25	106	39	67	24	20	7	6	2	7	3	273
17.....	61	24	87	34	75	29	24	9	6	2	6	2	258
18.....	60	26	84	36	65	28	15	6	4	2	6	2	233
19.....	46	23	72	36	50	30	13	7	4	2	5	2	199
20.....	43	26	58	34	51	30	13	8	2	1	2	1	169
21.....	25	17	47	33	49	34	11	8	6	4	5	4	143
22.....	23	23	34	34	34	34	5	5	2	2	2	2	100
23.....	18	26	20	28	20	28	11	16	1	1	1	1	71
24.....	12	21	16	28	19	33	6	10	2	4	2	4	57
25.....	3	12	6	26	8	34	3	12	1	4	3	12	24
26.....	2	20	4	40	3	30	1	10	0	0	0	0	10
27.....	1	20	2	40	1	20	1	20	0	0	0	0	5
28.....	0	0	1	33	2	67	0	0	0	0	0	0	3
29.....	0	0	1	50	1	50	0	0	0	0	0	0	2
Total fires.....	901		1,130		901		235		60		66		3,302

## A. WAGNER'S "CLIMATOLOGIE DER FREIEN ATMOSPHERE"

Abstract by J. C. BALLARD

This work, which is Volume I, Part F, of the new Handbuch der Klimatologie, contains a systematic treatment of a large amount of widely scattered upper-air observations. Wherever possible, temperature, humidity, pressure and wind conditions with respect to latitude, longitude, and topographical features have been summarized and discussed. Practically no references to clouds have been made.

A large section of the book deals with North America. This is subdivided as follows: (a) Temperatures found with the aid of kites, captive and limited-height sounding balloons, and airplanes; (b) Sounding balloon flights; (c) Relative humidity; (d) Pressure; (e) Wind.

The part dealing with temperatures contains tables of normals based on the latest available data for the standard levels up to 4 kilometers for Ellendale, N. Dak., Drexel, Nebr., Royal Center, Ind., Washington, D. C., Broken Arrow, Okla., Due West, S. C., and Groesbeck, Tex. Other tables show the free-air temperature distribution with latitude and longitude, vertical temperature gradients, and annual amplitudes. The discussion here, as throughout the book, is concise and confined to the most important features.

Although the sounding balloon data were relatively meager, comparison was made between the St. Louis-Omaha region and the Toronto-Woodstock region. The data from the series of sounding balloon observations

made during the winter of 1927-28 at 12 Weather Bureau stations were published too late to be included in this part, but a few notes have been added at the end of the book with regard to these data.

Smoothed means of the annual march of the relative humidity for altitudes up to 3 and 4 kilometers are given for the seven stations mentioned above.

Mean barometric pressures for various elevations for several stations are given and also a table of pressure gradients for longitude  $97^{\circ}$  W.

The section on wind contains tables dealing with air displacement, annual march of the wind velocity and direction, and maps showing mean stream lines for the 1, 2, and 3 kilometer levels. In the discussion of these tables important facts are brought out concerning the effect of the Rocky Mountains on the air displacement.

The second section, dealing with Europe, follows a plan of treatment similar to that for North America. Several tables showing temperatures are given, as well as the average temperature and height of the tropopause for several European stations. The sections on relative humidity and barometric pressure however, are not so well provided with data. Mean pressures, for each season and for the year are given for heights up to 16 kilometers for three stations, viz., Lindenberg, München, and Pavia. Considerable wind data are given for regions north of the Alps.

The third section of the work deals with wind distribution in the Mediterranean district. Data are included in the tables of this section for a number of countries, including Italy, the Balkans, Palestine, Turkey, and Algiers.

The region of the Tropics is next taken up and discussed under two headings, viz, temperature and wind.

A table of mean temperatures and lapse rates is given for Batavia, and also a table of the average height and temperature of the tropopause for the various months. A table of mean relative humidities for the wet and dry seasons for Batavia shows large differences between these two seasons.

Monthly means of air displacement are given for Batavia for heights up to 24 kilometers, and are based on several hundred observations. Wind data for other regions include central Africa, Honolulu, Samoa, and Mauritius. Mention is also made of Guam, San Juan, and Barranquilla.

The section relating to the Atlantic Ocean is comparatively short, especially that dealing with temperature, little actual data of which are given. However, the important features are mentioned and a few references given. No tables of wind values are given for the Atlantic Ocean, but mean stream lines are shown for winter and summer for the 1-1.5 kilometer and 4-5 kilometer levels.

A good discussion is given of the temperature and wind distribution over India.

Mean monthly and annual temperatures at Agra are shown for heights up to 20 kilometers. The temperature gradients, and the mean heights and temperatures of the tropopause for the various months have also been computed and are given for this station.

Wind data are given for eight stations for three characteristic months, viz, April, August, and December.

Various temperature tables based on kite and sounding balloon observations are given for the region of Spitzbergen and for the base of the British Antarctic expedition of 1911.

The part dealing with winds in the polar regions includes discussions and tables of data for the east and west coast of Greenland, Iceland, the Arctic Ocean, and the Weddell Sea.

The next section of the work deals with isolated sets of observations in the following countries: Egypt, Australia, New Zealand, Japan, Uruguay, and Russian Turkestan.

The part dealing with Egypt contains a table giving free-air pressures, temperatures, and humidities for Helwan. Upper-air wind directions are given for six stations.

The means of a large number of wind observations are given for Australia and New Zealand, and also mean temperatures based on 13 sounding balloon observations.

The means of several hundred wind observations are given for Tatenos, Japan, and the means of a lesser number for Montevideo and for Tashkent, in Russian Turkestan.

In the last section the author discusses the free-air temperature and pressure in a meridional section of the Northern Hemisphere. A figure has been drawn to represent the temperature and height of the tropopause along a meridian and with the aid of these temperatures the pressures in a meridional section have been computed. From the pressures a table of pressure gradients was computed and the general circulation discussed with reference to this table.

In this connection it was found that equatorially directed pressure gradients—i. e., lower pressure toward the Equator—occur in the following areas: In summer (1) at the surface between 30° and 10° and again between 90° and 70° latitude; (2) from 6 kilometers up to the greatest heights between 10° and 0°; (3) above 18 kilometers from the Pole to 50° to 40°. In winter (1) in the low levels between the horse latitudes and Equator; (2) above 18 kilometers between 10° and 30° latitude, (3) in the region of the Pole.

Relatively large poleward directed pressure gradients were found in winter at heights of 12 to 18 kilometers, between 0° and 10° latitude. Thus at these heights in winter, west winds theoretically can occur near the Equator. Such winds have been observed in the pilot balloon flights of Batavia.

The maxima pressure gradients were found, at the surface, to be between 50° and 60° latitude in summer and between 70° and 80° latitude in winter. In both seasons the maxima are displaced equatorially with increasing height.

## THE COLDER THE AIR THE THINNER THE ICE

By W. J. HUMPHREYS

It is a saying among certain Great Lakes fishermen that ice grows faster in zero (Fahrenheit) weather than it does when the temperature is considerably subzero. This, if true, is one of nature's many pleasing puzzles which it always is a delight to solve. But is it true?

Evidently the rate of thickening of the ice (at the under surface, of course) is proportional to the rate of loss of heat by the water up through the ice cover. Under steady conditions this rate in turn is proportional directly to the thermal conductivity of the ice and the difference in temperature between its upper and under surfaces, and indirectly to the thickness of the ice sheet. In other words, it is proportional to the conductivity of the ice and the temperature gradient through it. Now the conductivity of ice is a constant, nearly, if we neglect, or take into account and average, the effect of air bubbles and other irregularities. Also the temperature at the under surface of the ice is a constant, namely, 32° F., in the case of fresh water. We, therefore, can say that for any given thickness of the ice, the rate of its further

growth, under steady conditions, is directly proportional to the extent to which the temperature of its outer surface is below the freezing point. That is, it is proportional to  $32 - t_s$ , in which  $t_s$  is the temperature, as indicated by a Fahrenheit thermometer, of the upper surface. If, then, this upper surface always had the temperature of the air above it, there would be no occasion to explain the paradox in question, for there would be no paradox. But this relation does not always hold, and in that fact we have the solution of our fisherman's puzzle.

At temperatures around zero Fahrenheit there is not likely to be much fog drifting over the ice from the open water farther out in the lake, and often too at such times there is wind enough to keep the surface of the ice swept clean of snow. On the other hand, when the temperature of the air is considerably lower the "frost smoke," produced by the "steaming" of the open, deep water and remaining unevaporated at the low temperature, well may spread out slowly over the ice and thereby not only decrease the net loss of heat by radiation, as fogs and

clouds always do by the return radiation they themselves give out, but also decrease it, sometimes very greatly, by depositing over the ice an insulating sheet of finely powdered snow. Any substance, even a metal, when finely divided, is a poor conductor of heat, and snow is one of the poorest. Hence ice covered with a layer of fine snow, even though that layer be very thin, loses heat to colder air above much more slowly than it would if bare. Obviously, therefore, under otherwise like conditions ice increases in thickness much faster when bare than it does when snow covered.

Ice of any given thickness grows fastest when its surface is coldest; but this temperature depends in part on the condition of the air above—clear, cloudy, or foggy—and on the condition of its surface, clean or snow covered. And the fog blanket and the fine snow cover are most likely to form in relatively calm and very cold weather, drifted by the gentle movement of the air that commonly obtains on such occasions over and onto the ice sheet to the leeward of the remaining open water.

It well may be, therefore, as fishermen tell us, that at certain places, at least, along the shores of the Great Lakes more ice is formed occasionally, perhaps also on the average, when the temperature of the air is around zero Fahrenheit than there is when that temperature is even 20° to 30° lower, owing, as explained, to the greater prevalence of clear air and clean ice in the first case and foggy air and snowy ice in the second.

But here also, as everywhere and always, a few appropriate figures afford a very necessary check on one's general or qualitative reasoning. Let the conditions be:

- Temperature of the air  $-18^{\circ}\text{C.}$ ,  $0^{\circ}\text{F.}$ , approximately. Thickness of ice, 5, 10, 25, 50 centimeters, respectively. Snow covering, none.
- Temperature of the air  $-29^{\circ}\text{C.}$ ,  $-20^{\circ}\text{F.}$ , roughly. Thickness of ice, as in cases *a*. Snow covering, 1 millimeter.
- Same as *b* in respect to temperature of air and thickness of ice. Snow covering, 5 millimeters.

Now since the radiations of snow and ice at these low temperatures are small; the reflection of sunlight and sky-light by snow roughly 90 per cent; the amount of such radiation absorbed by ice also small, especially since there is not likely to be much of it to absorb in midwinter at latitude  $47^{\circ}\text{N.}$ , say; and the heat conductivity of ice very low; therefore, as a first approximation, we may assume the temperature of the top surface of the snow or bare ice

to be that of the adjacent air. The temperature of the under surface of the ice is, of course,  $0^{\circ}\text{C.}$  Furthermore, as experiment has shown, the conductivity of very loose snow may be as low as one three-hundredths that of ice. Assume it, in the present case, to be one one-hundredth that value, so that as a heat insulator, a layer of our fine snow 1 millimeter deep is the equivalent of a sheet of ice 100 times as thick, 10 centimeters; a 5-millimeter covering of snow the equivalent of a 50-centimeter sheet of ice; and so on for other depths and thicknesses.

In case *a* the difference in temperature between the under and upper surfaces of the ice is  $18^{\circ}\text{C.}$ , and in cases *b* and *c* the difference between the temperature of the under surface of the ice and top surface of the snow  $29^{\circ}\text{C.}$  Therefore our various temperature gradients, in terms of centigrade degrees and thicknesses, or equivalent thicknesses, in centimeters, of ice are as given in the following table:

Temperature gradients

Thickness of ice, centimeters.....	5	10	25	50
Bare; air $-18^{\circ}\text{C.}$ .....	196	1960	1966	1960
1 millimeter snow; air $-29^{\circ}\text{C.}$ .....	3966	3960	3966	3960
5 millimeters snow; air $-29^{\circ}\text{C.}$ .....	3966	3960	3966	3960

From these gradients it is clear that often bare ice can grow faster when the temperature of the air is  $0^{\circ}\text{F.}$  than can snow-covered ice of the same thickness when the air is much colder, even  $-20^{\circ}\text{F.}$  When the thickness of the ice is 16.3 centimeters (6.4 inches) it grows just as fast in  $0^{\circ}\text{F.}$  weather, if bare, as it would with a 1-millimeter covering of loose snow (conductivity of snow one one-hundredth that of ice) in weather at  $-20^{\circ}\text{F.}$  If thinner, the bare ice would grow faster than the snow covered at the given temperatures, and if thicker it would grow slower. If the depth of the snow were 5 millimeters the thickness of the ice would need to be 81.8 centimeters (32.2 inches) for the rates of growth under the given conditions to be the same.

In the first of these cases the rate of increase of thickness is about 1 centimeter in four hours, the conductivity of ice being 0.005 (transmitting 0.005 calory per second per square centimeter cross section when the temperature gradient is  $1^{\circ}\text{C.}$  per centimeter), and in the second case 1 centimeter in 20 hours.

Thus the fisherman's interesting paradox, the colder the air the thinner the ice, has become orthodox and lost its fascination.

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## SOLAR OBSERVATIONS

## SOLAR RADIATION MEASUREMENTS DURING FEBRUARY, 1932

By HERBERT H. KIMBALL, in charge Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1932 REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged above the normal intensity for February at Washington, close to the February normal at Lincoln, and slightly below at Madison.

Table 2 shows an excess in the total solar radiation received on a horizontal surface at Chicago, New York, Fresno, Pittsburgh, Twin Falls, La Jolla, and Miami, and a deficiency at Washington, Madison, Lincoln, and Gainesville.

No skylight polarization measurements were obtained during the month. At Madison the presence of snow in the vicinity of the station made such readings of doubtful value, and at Washington the polarimeter was undergoing repairs.

TABLE 1.—Solar radiation intensities during February, 1932

[Gram-calories per minute per square centimeter of normal surface]

## Washington, D. C.

Date	Sun's zenith distance											Local mean solar time
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon	
	75th mer. time	Air mass										
		A. M.					P. M.					
		e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	
Feb. 1.....	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.	
Feb. 5.....	1.24	0.86	0.97	1.14	1.28	1.44	1.30	1.15	0.92	0.78	1.32	
Feb. 8.....	2.36	—	—	—	1.22	—	1.24	—	—	—	2.26	
Feb. 11.....	7.57	—	—	—	—	—	1.25	1.00	0.92	0.75	6.50	
Feb. 13.....	4.42	0.92	1.00	1.09	—	—	—	—	—	—	2.26	
Feb. 16.....	2.16	—	0.85	1.00	1.18	—	—	—	—	—	2.26	
Feb. 18.....	1.96	0.82	0.92	1.13	1.33	1.46	1.17	—	—	—	1.96	
Feb. 20.....	2.06	0.97	1.11	1.24	1.41	1.55	—	—	—	—	1.96	
Feb. 23.....	1.68	—	—	—	—	—	1.16	0.95	—	—	1.82	
Feb. 26.....	4.37	0.81	0.92	0.78	—	—	—	—	—	—	4.75	
Means.....	—	0.82	0.92	1.06	1.28	1.48	1.22	(1.02)	(0.92)	(0.75)	—	
Departures.....	—	+0.10	+0.10	+0.07	+0.10	-0.01	+0.03	+0.04	+0.06	-0.01	—	

¹ Extrapolated.

TABLE 1.—Solar radiation intensities during February, 1932—Continued

[Gram-calories per minute per square centimeter of normal surface]

## Madison, Wis.

Date	Sun's zenith distance										Local mean solar time	
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°		
	75th mer. time	Air mass										
		A. M.					P. M.					
		e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0		5.0
Feb. 3.....	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.	
Feb. 4.....	1.37	0.73	0.93	1.18	1.34	—	1.34	1.22	—	—	1.52	
Feb. 5.....	1.88	—	—	—	—	—	1.37	1.15	—	—	1.78	
Feb. 8.....	1.96	—	—	1.05	1.23	—	—	1.16	—	—	2.40	
Feb. 11.....	2.87	0.95	1.12	1.29	1.45	—	—	—	—	—	1.24	
Feb. 12.....	2.26	0.82	1.00	1.17	1.40	—	—	—	—	—	1.88	
Feb. 13.....	1.32	0.93	1.05	1.21	1.41	—	—	—	—	—	1.24	
Feb. 18.....	1.52	—	—	—	1.25	—	—	—	—	—	2.62	
Feb. 20.....	2.06	—	0.98	—	—	—	—	—	—	—	2.16	
Feb. 23.....	1.12	—	0.82	—	1.20	—	—	—	—	—	1.02	
Feb. 26.....	4.75	—	—	1.14	—	—	—	—	—	—	5.56	
Feb. 27.....	4.05	—	—	—	1.19	—	—	—	—	—	5.16	
Feb. 29.....	3.45	—	—	—	1.24	1.49	—	—	—	—	3.63	
Means.....	—	0.86	0.96	1.18	1.33	—	(1.36)	1.16	—	—	—	
Departures.....	—	-0.06	-0.16	-0.02	-0.03	—	+0.00	+0.01	—	—	—	

## Lincoln, Nebr.

Feb. 3	0.96		0.78	0.98							0.86
Feb. 4	0.81		1.01	1.20	1.21						0.96
Feb. 5	2.36			1.15	1.33						3.45
Feb. 6	3.63	0.81	0.89	1.08	1.28						3.45
Feb. 11	4.17		1.05	1.22	1.36		1.39	1.22	1.05	0.85	3.99
Feb. 12	2.87							1.31	1.18	1.08	2.87
Feb. 17	1.62	1.06	1.18	1.31	1.45		1.45	1.08	0.84	0.81	1.68
Feb. 19	2.16		1.04	1.25	1.41		1.41	1.00	0.93		2.36
Feb. 22	1.96	0.98	1.01	1.13	1.38		1.23				2.87
Feb. 25	4.95	0.84	0.91	1.11	1.34						5.36
Means	0.95		0.98	1.15	1.34		1.37	1.18	1.00	0.91	
Departures	+0.01	-0.03	-0.03	-0.03	-0.03		+0.02	+0.02	-0.03	-0.01	

¹ Extrapolated.

TABLE 2.—Average daily totals of solar radiation (direct + diffuse) received on a horizontal surface  
[Gram-calories per square centimeter]

Week, beginning	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Gainesville	Miami	New Orleans
Jan. 29	cal. 146	cal. 175	cal. 244	cal. 107	cal. 96	cal. 196	cal. 118	cal. 20	cal. 191	cal. 318	cal. 256	cal. 375	cal. 216
Feb. 5	202	156	270	121	169	295	140	55	184	250	236	425	216
12	228	221	305	187	232	338	219	51	311	238	239	440	216
19	270	285	308	254	267	418	168	102	358	364	205	394	171
Departures from weekly normals													
Jan. 29	-51	-14	+12	-6	-43	-44	-3	-----	+4	+62	-----	+19	-----
Feb. 5	+6	-80	+8	-4	+28	+19	-5	-----	-36	+1	-36	+57	-----
12	+2	-7	-70	+48	+72	+67	+54	-----	+48	-41	-52	+70	-----
19	+14	+38	+7	+80	+75	+62	+6	-----	+80	+40	-110	+30	-----
Accumulated departures on February 25													
	-721	-1,785	-917	+651	+448	+1,533	+91	-----	-49	+1,456	-----	+2,527	-----
14-day mean.							16-day mean.						

#### ATMOSPHERIC DEPLETION OF SOLAR RADIATION

The primary object of the measurements of screened solar radiation,  $I$ , and  $I_r$  given in Table 3, is to determine the value of the coefficient of atmospheric turbidity,  $\beta$ , or the atmospheric depletion of solar radiation by scattering, aside from the scattering by the gas molecules of dry air.

According to Fowle and others, the depletion of solar radiation of a given wave length,  $\lambda$ , through atmospheric scattering, may be expressed by the equation

$$(1) \quad I_\lambda = I_{0\lambda} e^{-(a_1 + a_2)m}$$

Here,  $I_\lambda$  = the measured intensity of solar radiation of wave length  $\lambda$ ;

$I_{0\lambda}$  = the intensity of radiation of the same wave length before it entered the atmosphere;

$e$  = the base of the Napierian system of logarithms;

$a_1$  = the coefficient of extinction of solar radiation of wave length  $\lambda$ , through scattering by atmospheric gas molecules.

$a_2$  = the coefficient of extinction through scattering by other constituents of the atmosphere, principally dust, and which also may be represented by  $\frac{\beta}{\lambda^a}$ . For ordinary

atmospheric dust  $a = 1.3$ , as contrasted with 4.0 for molecular scattering. Therefore, while the scattering for dust is a function of the wave length,  $\lambda$ , the value of the coefficient,  $\beta$ , is independent of wave length.

$m$  = the air mass, or the length of the path of the solar rays through the atmosphere in terms of its length when the sun is in the zenith, or approximately the secant of the sun's zenith distance.

In Smithsonian Meteorological Tables, Fifth Revised Edition, 1931, Table 111 gives values of  $I_{0\lambda}e^{-a_1}$ , or  $a_{0\lambda}$ , the atmospheric transmission coefficient for pure dry air at a pressure of 760 millimeters, for wave lengths between 0.3504  $\mu$  and 2.442  $\mu$ . There are also given values of the relative intensity of solar radiation before it entered the atmosphere,  $e_{0\lambda}$ , over the same range of wave lengths, and likewise its intensity after passing through pure dry air at 760 millimeters pressure. At the foot of each column of Table 111 will be found the relative intensity

of energy in selected sections of the spectrum, and it may be determined for any section desired.

From this table the curves of Figure 1, page lxxxiv were constructed, except that the latter do not include the absorption by the permanent gases of the atmosphere, which is given near the foot of columns 5 to 10, Table 111.

It therefore becomes possible to determine from the data of Table 111 the solar radiation intensity between any desired spectrum limits after depletion by pure dry air, provided a constant value for the solar output of radiant energy is assumed. Apparently such an assumption is within the probable error of the screened measurements, since 1,007 solar constant determinations made at Mount Montezuma, Chile, between August 1, 1925, and July 31, 1931, give a standard deviation of  $\pm 0.00856$ .

The red-glass filter obtained from the Potsdam Observatory transmits about 90 per cent of the radiation between wave lengths 0.625 and 2.850  $\mu$ , or the section of the solar spectrum that includes all the important atmospheric absorption bands except those due to ozone. If, therefore, the intensity as measured is divided by the transmission coefficient for the filter and subtracted from the intensity for the entire spectrum as given by a pyrheliometric reading, the remainder will give the intensity in that part of the spectrum below 0.625  $\mu$ , which is relatively free from atmospheric absorption bands. Then the difference between the measured intensity of radiation below 0.625  $\mu$  and the intensity determined from Table 111 will give the depletion, in this part of the spectrum by dust, including what Fowle has designated wet dust, and some absorption by ozone. This latter must be a very small amount, since Fowle has estimated the entire absorption of solar radiation of wave length greater than 0.350  $\mu$  by the permanent gases of the atmosphere to be only 0.012 gr. cal. per min. per sq. cm.<sup>1</sup> and by ozone, between wave lengths 0.450  $\mu$  and 0.650  $\mu$  to be between 0.002 and 0.010 gr. cal.<sup>2</sup>

The above steps may be expressed mathematically as follows:

$$(2) \quad I_m - \frac{1}{\gamma} I_r = \int_0^{0.625\mu} I_{0\lambda} \psi(m, \beta, \lambda) d\lambda.$$

This equation may be adapted to a screen of slightly different transmission coefficients and wave-length limits as follows:

$$(3) \quad bI_m - c \frac{1}{\gamma} I_r = \int_0^{0.625\mu} I_{0\lambda} \psi(m, \beta, \lambda) d\lambda.$$

Ångström integrated equation (2) for an upper wave-length limit of 0.600  $\mu$  and for different values of  $\beta$  and  $m$ , and plotted these integrals as ordinates against  $m$  as abscissas. The integrals for different values of  $\beta$  fall on curves that meet at the point where the curve for  $\beta = 0$  (no depletion from dust) cuts the ordinate for zero atmosphere. (Geografiska Annaler, Årg. xii, Heft 2, och 3, 1930, p. 142, fig. 5.)

To adapt readings,  $I_r$ , obtained with the red filters furnished by Potsdam to his diagram, Ångström<sup>3</sup> found that in equation (3)

$$b = 0.95 \text{ and } c = 1.09$$

I have applied these factors to measurements obtained at Washington with the results given in Table 3.

<sup>1</sup> Smithsonian Meteorological Tables, Fifth Revised Edition, 1931, p. lxxxiv and Table 111.

<sup>2</sup> Fowle, Frederick E. Atmospheric Ozone: Its relation to some solar and terrestrial phenomena. Smithsonian Misc. Coll. vol. 81, No. 11, p. 8.

<sup>3</sup> Geografiska Annaler. Årg. XII, Heft 2 och 3, 1930. Footnote, p. 144.

TABLE 3.—Solar radiation measurements, and determination of the atmospheric turbidity factor,  $\beta$ . Washington, D. C., February, 1932

[Values in italics have been interpolated]

Date and solar hour angle	Solar altitude, $\alpha$	Air mass, $m$	$I_0$	$I_1$	$I_2$	$\beta$	Blue-ness of sky (scale, 0-14)	Atmospheric dust particles per cubic centimeter	Notes
Feb. 1									
3:46 a.	13-28	4.23	0.921	0.739	0.649	0.085		905	
3:52 a.	16-42	3.44	1.075	.783	0.681	.090			
3:54 a.	19-15	3.02	1.127	.834	.691	.090			
2:30 a.	23-45	2.48	1.207	.894	.781	.090			
2:21 a.	24-50	2.37	1.181	.901	.724	.090			
1:42 a.	28-53	2.06	1.216	.911	.733	.088	5		
0:07 a.	33-46	1.80	1.308	.910	.750	.070			
0:06 p.	33-47	1.79	1.331	.910	.752	.065			Stopped by clouds.
Feb. 5									
1:39 p.	30-15	1.98	1.238	.911	.700	.065	5	611	
1:46 p.	29-42	2.02	1.246	.908	.702	.060			Clouds, a. m.
Feb. 8									
2:19 p.	26-53	2.21	1.222	.895	.739	.070	6	1,140	
2:26 p.	26-06	2.27	1.207	.891	.724	.072			Clouds, a. m., now disappearing.
3:06 p.	20-38	2.82	1.136	.848	.681	.058			
3:13 p.	19-35	2.97	1.084	.824	.671	.065			
3:40 p.	15-24	3.73	.994	.735	.624	.075			
Feb. 13									
3:17 a.	20-23	2.85	1.099	.839	.645	.055		410	
2:43 a.	25-23	2.32	1.168	.859	.678	.065			
2:34 a.	26-34	2.23	1.203	.870	.682	.058			
1:18 a.	34-30	1.80	1.282	.918	.725	.070			
1:10 a.	35-00	1.76	1.288	.920	.727	.070			Clouds, p. m.
Feb. 16									
3:30 a.	19-22	3.01	.988	.736	.611	.075		1,132	
2:48 a.	25-24	2.32	1.115	.837	.672	.070			Much smoke over city.
2:41 a.	26-18	2.24	1.143	.840	.685	.082			
2:02 a.	31-08	1.94	1.157	.850	.700	.110	4		
1:56 a.	31-56	1.88	1.164	.853	.697	.115			Clouds, p. m.
Feb. 18									
3:37 a.	18-23	3.16	1.111	.827	.706	.065		284	
3:02 a.	23-48	2.48	1.165	.875	.716	.076			
2:55 a.	24-53	2.38	1.189	.888	.725	.074			
2:35 a.	27-41	2.18	1.282	.930	.754	.062			
2:26 a.	29-19	2.08	1.293	.946	.768	.065			
2:19 a.	29-46	2.06	1.314	.960	.778	.064	5		
0:50 a.	37-52	1.63	1.372	1.005	.778	.070			
0:44 a.	38-16	1.60	1.384	1.004	.780	.068			
0:52 p.	37-52	1.62	1.324	.982	.752	.080			
1:02 p.	37-14	1.64	1.278	.924	.752	.106			
1:58 p.	32-18	1.88	1.170	.875	.702	.106			
2:04 p.	31-38	1.90	1.158	.852	.690	.090			Stopped by clouds.
Feb. 20									
3:51 a.	16-33	3.46	1.162	.901	.737	.045		746	
3:46 a.	17-32	3.30	1.203	.916	.740	.045			
3:25 a.	19-16	3.01	1.239	.935	.760	.042			
3:01 a.	24-25	2.38	1.328	.984	.777	.042			
2:54 a.	25-36	2.31	1.350	.991	.783	.040			
2:45 a.	26-54	2.20	1.367	1.000	.791	.040			
2:36 a.	28-13	2.12	1.381	1.010	.802	.045			
2:29 a.	29-05	2.05	1.382	1.014	.815	.052			
2:24 a.	29-45	2.01	1.398	1.014	.815	.050	6		
0:46 a.	38-46	1.60	1.453	1.009	.798	.045			
0:36 a.	39-13	1.58	1.445	.999	.794	.045			
Feb. 23									
1:20 a.	37-36	1.64	1.218	.891	.716	.115		561	
1:14 a.	38-04	1.62	1.222	.891	.716	.112			
3:06 p.	24-44	2.38	1.093	.792	.634	.075			
3:11 p.	23-53	2.46	1.060	.788	.634	.092			
3:31 p.	20-28	2.85	.976	.708	.598	.082			Stopped by clouds.

## POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column.]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longi- tude	Lat- tude	Spot	Group	
1932							
Feb. 1 (Naval Observatory).....	11 4	+3.0	172.4	+13.0	77		
		+70.0	239.4	-13.0	62		139
Feb. 3 (Naval Observatory).....	13 38	+31.0	172.6	+13.5	62		62
Feb. 4 (Yerkes Observatory).....	12 19	+43.5	172.7	+12.8	88		88
Feb. 5 (Naval Observatory).....	10 28	+56.0	173.0	+13.0	46		46
Feb. 6 (Yerkes Observatory).....	15 10	+70.7	171.9	+12.9	100		100
Feb. 7 (Naval Observatory).....	11 35		No spots				
Feb. 8 (Naval Observatory).....	14 46		No spots				
Feb. 9 (Naval Observatory).....	11 34		No spots				
Feb. 10 (Naval Observatory).....	14 44	-1.0	47.8	-5.0		25	25
Feb. 11 (Naval Observatory).....	11 3	+12.0	49.7	-6.0		15	15
Feb. 12 (Yerkes Observatory).....			No spots				
Feb. 13 (Naval Observatory).....	11 0		No spots				
Feb. 14 (Yerkes Observatory).....			No spots				
Feb. 15 (Naval Observatory).....	11 5		No spots				
Feb. 16 (Naval Observatory).....	10 42		No spots				
Feb. 17 (Yerkes Observatory).....			No spots				
Feb. 18 (Naval Observatory).....	11 47		No spots				
Feb. 19 (Naval Observatory).....	14 31		No spots				
Feb. 20 (Naval Observatory).....	10 32		No spots				
Feb. 21 (Yerkes Observatory).....			No spots				
Feb. 22 (Naval Observatory).....	12 51		No spots				
Feb. 23 (Naval Observatory).....	10 38	-48.0	191.9	+5.0		31	
		-6.0	233.9	-12.0		31	
		-1.0	238.9	-15.0		12	74
Feb. 24 (Mount Wilson).....	10 50	-33.0	193.6	+5.0		45	
		+7.0	233.6	-12.0		17	
		+14.0	240.6	-15.0			66
Feb. 25 (Naval Observatory).....	10 49	-18.0	195.5	+5.0	4	278	278
Feb. 26 (Naval Observatory).....	10 46	-4.5	195.8	+5.0		432	432
Feb. 27 (Naval Observatory).....	11 5	+10.0	197.0	+5.0		463	463
Feb. 28 (Mount Wilson).....	12 30	-65.0	108.0	+13.0		248	
		+24.0	197.0	+4.0		351	599
Feb. 29 (Naval Observatory).....	10 47	-52.0	108.8	+12.5		278	
		+37.0	197.8	+5.5		309	587
Mean daily area for Febru- ary.....							
							106

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR FEBRUARY, 1932<sup>1</sup>

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

February, 1932	Relative numbers	February, 1932	Relative numbers	February, 1932	Relative numbers
1	19	11	9	21	0
2	16	12	7	22	0
3	17	13	0	23	Ec 18
4	8	14	0	24	23
5	8	15	0	25	26
6	8	16	0	26	26
7	7	17	0	27	d 39
8	7	18	0	28	31
9		19	0	29	29
10	9	20	0		

Mean: 28 days=11.0.

<sup>1</sup> Dependent alone on observations at Zurich and its station at Arosa.

a= Passage of an average-sized group through the central meridian.

b= Passage of a large group or spot through the central meridian.

c= New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.

d= Entrance of a large or average-sized center of activity on the east limb.

## AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG, in charge]

By L. T. SAMUELS

The mean free-air temperatures for the month were considerably above normal at most stations. (See Table 1.) The largest departures occurred at Dallas and Omaha around the 1,500 and 2,000 meter levels. Temperature departures were negative at all levels at San Diego and at the lower levels at Washington, D. C. Relative humidities were close to normal in most cases, the largest departures occurring at Cleveland, where they were negative, and at Dallas, where they were positive.

Free-air resultant wind directions for the month were close to normal, while the velocities were in general slightly above normal.

The highest airplane observation during the month was 6,610 meters above sea level and was made at Dallas on the 5th. The highest average height during the month was 5,991 meters above sea level and was obtained at Omaha.

TABLE 1.—Free-air temperatures and relative humidities during February, 1932

Altitude (meters) m. s. l.	Chicago, Ill. (190 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (149 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Hampton Roads, Va. (2 meters)		Omaha, Nebr. (299 meters)		Pensacola, Fla. (2 meters)		San Diego, Calif. (9 meters)		Washington, D. C. (2 meters)	
	TEMPERATURE (° C.)																			
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	-1.4	-0.6	0.1	+0.9	10.0	+1.1	9.1	+1.1	-9.8	-0.1	7.1	+1.9	-3.4	+0.1	15.7	+3.8	12.9	-0.4	0.3	-1.6
500	-1.9	-0.8	-0.3	+2.4	11.1	+3.4	9.7	+2.3	-9.5	+0.2	5.9	+1.3	-2.8	+1.0	15.8	+3.7	11.3	-1.0	-0.2	-1.8
1,000	-1.6	+2.3	-1.8	+2.0	11.8	+4.6	9.0	+3.1	-6.5	+2.1	4.9	+1.7	-0.1	+3.3	14.1	+4.0	9.1	-1.6	-1.3	-0.7
1,500	-1.5	+3.3	-3.0	+1.8	11.3	+5.4	7.5	+3.5	-4.7	+3.4			1.6	+4.6						
2,000	-2.9	+3.4	-4.5	+1.8	9.1	+5.1	5.5	+3.4	-6.1	+3.4	2.3	+2.0	0.6	+4.9	9.2	+3.3	4.4	-1.4	-3.4	+0.1
2,500	-5.3	+2.9	-6.1	+2.1	6.2	+4.6	2.6	+2.9	-8.8	+3.0			-1.9	+4.6						
3,000	-7.7	+2.9	-8.4	+2.2	3.4	+4.3	0.3	+3.1	-11.4	+3.1	-3.4	+0.9	-4.4	+4.7	4.4	+3.1	-1.5	-2.6	-6.4	+1.2
4,000	-13.2	+3.3	-13.9	+2.6	-3.6	+2.2			-16.9	+2.9			-10.4	+4.3						
5,000			-20.4	+2.6	-11.2	+0.3							-17.2	+4.3						

## RELATIVE HUMIDITY (PER CENT)

Surface	78	0	84	+6	82	+7	77	+7	84	+3	76	+3	87	+10	79	-2	66	-2	69	-2
500	76	-2	83	+5	73	+4	67	+3	83	+3	74	+10	83	+8	69	+1	64	+1	64	0
1,000	65	-6	81	+10	65	+6	59	-1	69	-1	66	+8	68	+4	70	+5	60	+4	58	-3
1,500	55	-7	72	+10	57	+5	55	-1	60	-2			58	+1						
2,000	51	-6	63	+6	54	+7	50	-3	60	+1	54	+7	54	+1	65	+7	48	+5	54	0
2,500	49	-7	55	-1	54	+10	46	-5	59	0			56	+4						
3,000	47	-10	51	-6	53	+11	43	-6	53	0	54	+11	55	+3	59	+11	41	+10	50	-1
4,000	48	-9	60	-7	53	+17			58	+3			53	+3						
5,000			62	-6	48	+16							50	0						

\* Normals for Royal Center, Ind., used.

\* Normals determined by interpolating between those for Groesbeck, Tex., and Broken Arrow, Okla.

\* Naval air station.

\* Normal for Drexel, Nebr., used.

TABLE 2.—Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during February, 1932

[Wind from N=300°, E=90°, etc.]

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,373 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	360	0.5	173	1.9	205	1.0	276	5.8	281	2.3	254	3.2	105	0.4	316	0.5	289	2.2	256	2.2	305	1.2	92	2.3
500			167	7.2	255	3.5			284	4.8	261	6.6	193	2.7	297	1.9	296	2.9			310	2.3	104	4.3
1,000			186	6.3	281	7.2			275	10.3	263	4.8	263	4.8	288	4.5	295	6.5	253	7.1	272	4.0	110	3.1
1,500			196	3.6	307	12.0			281	13.6	276	13.3	209	7.0	274	7.3	295	11.1	268	10.3	273	4.1	180	1.1
2,000	259	2.8	247	2.7	305	14.6	273	9.0	286	15.5	275	15.3	272	8.1	278	10.2	292	12.9	273	11.2	293	6.3	138	1.1
2,500	256	4.5	252	3.5	301	16.1	281	15.4	299	13.7	276	15.3	280	8.2	283	12.6	289	13.5	280	11.9			189	1.3
3,000	258	8.1	272	5.4			278	14.3			277	9.5	291	13.5	288	12.9	288	12.9	280	10.5			243	1.7
4,000	256	12.1					274	10.3					273	7.0	287	10.0								
5,000	294	7.1					288	12.0							270	14.4								

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (85 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	346	0.5	151	0.3	167	0.2	56	0.5	350	0.8	307	0.6	42	0.5	111	1.4	172	0.9	120	0.1	173	2.2	319	1.0
500	60	0.8	215	0.2	243	3.1	170	2.2	6	2.5	210	2.7	268	1.0	134	1.3			241	0.9	216	6.1	296	6.5
1,000	83	2.2	199	0.9	257	4.6	223	3.5	18	4.3	245	6.3	289	5.7	196	1.7			294	4.5	226	5.2	296	10.9
1,500	92	2.0	238	1.9	283	7.2	235	3.0	354	3.5	257	7.0	280	8.1	198	2.6			323	5.9	286	3.6	305	14.1
2,000	75	1.9	263	2.9	254	7.8	267	2.9	6	3.5	270	8.0	276	10.4	215	3.6	216	2.6	319	10.5	351	4.0	303	17.2
2,500	143	2.2	306	4.3	268	8.3	277	2.6	3	4.2	273	9.4	280	13.3	234	3.3	258	3.1	324	12.1	331	9.7	314	13.3
3,000	1	2.0	299	4.6	364	8.9			358	5.5	250	9.2	276	14.9	266	4.8	285	4.3						
4,000													283	16.7	275	3.9	286	5.4						
5,000	309	3.4	323	7.4	251	11.1			26	4.4	271	7.2			342	2.0								

## WEATHER IN THE UNITED STATES

(Climatological Division, OLIVER L. FARRIS in charge)

## THE WEATHER ELEMENTS

By M. C. BENNETT

## GENERAL SUMMARY

Unusually mild weather continued during February in practically all sections east of the Rocky Mountains, making the sixth consecutive month with abnormally high temperatures in these regions. However, a small area in the far Northeast averaged slightly colder than normal. Elsewhere from the Great Plains eastward the average temperature was from 5° to 10° above normal, with the greatest departures from the Ohio and lower Missouri Valleys southward. On the other hand, the central Plateau region had decidedly cold weather, the monthly average being from 3° to 12° below normal, while elsewhere from the Rocky Mountains to the Pacific about normal temperatures prevailed.

More than normal precipitation was received during February from northern Georgia and Tennessee westward, and in the west Gulf district, the far Southwest, and a few limited areas in the northern part of the country. On the other hand, the Atlantic coast area received generally less than normal, while very dry weather prevailed in Florida, much of the Lake region, the central valleys, the Northwest, and the central Pacific district.

## TEMPERATURE

While there was some decidedly cold weather during the first week, especially in the northern Rocky Mountain and Plains States, yet this week was mainly warmer than normal from the Continental Divide eastward, save in Minnesota and the Dakotas. It averaged much warmer than normal in the Gulf and South Atlantic States and the Ohio Valley. However, beyond the Rocky Mountains this week was colder than normal save near the Mexican border.

For a fortnight centering about the middle of the month the eastern half of the country was almost constantly warmer than normal, notably the Gulf States, and the central Plains also had mild weather. Much of the western half experienced cold weather, particularly the middle and northern Plateau.

In most of New York and New England cold weather set in about the 15th, and the remainder of the month was largely colder than normal, notably in eastern and northern New England. Save for this area, the closing week of February was warmer than normal in every State, especially over the middle and upper Mississippi Valley, the Plains, and the Rocky Mountain region.

As a whole, February was another surprisingly mild month over nearly every portion from the Rocky Mountains eastward. The month averaged from 7° to 11° warmer than normal in the Ohio, middle Mississippi, and lower Missouri Valleys, and everywhere southward to the Gulf of Mexico, also in Oklahoma and northern and eastern Texas. Practically all stations in these areas found it among the mildest Februaries of record, while in the lower Mississippi Valley and close to the Gulf coast it was almost everywhere the very warmest. In New England and from western Lake Superior to Montana the month was only moderately warmer than normal.

This was the sixteenth consecutive month warmer than normal at Williston, N. Dak., and the ninth over a large

part of the section east of the Mississippi River. At some stations on or near the Mississippi River it was the sixth consecutive month to average at least 5° warmer than normal and the fourth to average at least 8° warmer. In the Southeast it usually concluded the mildest winter (December to February, inclusive) of record, but in the Lake region, Ohio Valley, and central valleys it was usually not quite so warm as the winter of 1889-90.

Generally in the Pacific States, Idaho, Nevada, and Utah the month was colder than normal. In northern Nevada and districts adjacent there was a deficiency of at least 6° per day. At Winnemucca, Nev., Pocatello, Idaho, and Modena, Utah, this was the fourth consecutive month to average at least 3° colder than normal.

The highest temperatures in about half of the States were between 80° and 90°, but in several northern border States they were below 70°. The highest of all was 97° at Blanco, Tex., on the 7th. As a rule, the States of the eastern half noted their highest marks about the 10th, but a few northern States from Minnesota eastward joined the Western States in attaining their highest during the final five days of the month.

The lowest temperatures occurred chiefly during the opening week, but in Minnesota and some of the Middle Atlantic States during the last decade. However, the very lowest reported, -49°, at Seneca, Oreg., occurred on the 14th. Most other States of the far West and the northern border States reported at least -20° reached locally, but several Gulf States recorded no marks as low as +20°, and from New Jersey, Maryland, Ohio, Indiana, and Illinois southward there were no zero temperatures.

## PRECIPITATION

February differed from the two months next preceding in that more than half of the States fell short of the normal precipitation. For nearly all the country there was much more precipitation before the 16th than in the period thenceforward. Usually the first week brought most precipitation from Tennessee and the Carolinas northeastward, but the second week brought most in the vicinity of Lake Michigan and to southwestward over the center of the country. In the far Southwest each of these weeks brought large amounts.

The final fortnight did bring much precipitation to the extreme Northwest, particularly the western half of Washington. Also between the 16th and 21st much of the cotton region had heavy rainfall.

As a whole, the month brought much more than normal precipitation in southernmost districts to westward of the Mississippi River. Arizona and the southernmost portion of California received far more than normal and the greater part of Texas decidedly more than normal, while most of Arkansas and Tennessee and considerable areas adjacent to them had above-normal amounts.

There was somewhat more precipitation than normal in northern Michigan and northwestern Wisconsin, also in western Washington.

The monthly amounts were much less than normal in central and northern Florida, and in most coast districts to northeastward as far as Massachusetts, also in Missouri and Kansas, save their southeastern portions, and in South Dakota and northern Wyoming, and in northwestern California and southwestern Oregon. Moderate deficiencies were reported from eastern Louisiana to southern Alabama, in the central portions of North

Carolina and Virginia, from Pennsylvania and western New York west to Illinois and southern Wisconsin, in most of Nebraska, North Dakota, and northern and western Minnesota, usually in the middle and northern Rocky Mountain regions and the northern and western Plateau, and in central California.

The greatest monthly amount at a single station was 31.29 inches, at a point in western Washington; in the eastern half of the country the greatest amount was reported from a station in Louisiana, 10.96 inches.

#### SNOWFALL

There was little snowfall in the majority of States; especially there was again almost none from the middle Mississippi Valley eastward to the middle Atlantic coast, where the present cold season has set new records at many stations for least snowfall and briefest duration of snow cover. As a rule, there was somewhat less than normal from New England to Wisconsin and Iowa, likewise in the Plains States and the near Southwest.

Near Lake Superior the snowfall usually exceeded the normal, as it did in most portions of the Plateau States,

and generally in the mountainous portions of western Washington and southern California.

The supply of stored snow in the higher portions of the West was mainly quite large as the month ended. In the central Plateau States particularly it was nearly everywhere greater than normal, and in most portions of the Pacific States besides.

#### SUNSHINE AND RELATIVE HUMIDITY

More than the usual amount of sunshine for February prevailed in the Florida Peninsula, in much of the Missouri Valley, and in western Nevada and northern California; while generally in Texas and Oklahoma and to westward, including the far Southwest, much less than the average was received. In most other areas about the normal amounts prevailed. The relative humidity was generally above the normal in much of the Gulf region, the central Missouri valley, the western Rocky Mountain and Plateau areas, and the far Southwest, while it was below the monthly average in the central Mississippi and Ohio Valleys, the central Atlantic States, the western portion of the Great Plains, and the Pacific area. The departures from the normal were in no case large.

#### SEVERE LOCAL STORMS, FEBRUARY, 1932

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards) <sup>1</sup>	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Illinois (central).....	3				\$15,000	Glaze.....	Interurban trains delayed; motor traffic difficult; some loss to telephone company.	Official, U. S. Weather Bureau.
Baltimore, Md., and vicinity.	4					Wind.....	Trees uprooted; telephone and light service interrupted.	Do.
Dennison, Tex.....	10	11:30 p. m.	3 mi.			do.....	Wires and several small houses blown down.....	Do.
Scranton, Pa., and vicinity.	10	P. m.				Severe thunderstorm.	Streets and basements flooded.....	Do.
Oklahoma (south-central and eastern).	10-11					Destructive wind.	Character of damage not reported.....	Do.
Buffalo, N. Y., and vicinity.	11	A. m.			8,000	Thunderstorm.....	Teletype service interrupted; barn and contents destroyed by lightning.	Do.
Dallas, Tex.....	11	A. m.				Wind.....	Roof caved in, plate glass broken; signs blown down.	Do.
Brookville, Ind.....	11	11:45 a. m.			3,500	do.....	Buildings damaged; 2 persons injured.	Do.
Cincinnati, Ohio.....	11	1:09-1:15 p. m.				Wind squall.....	Some property damaged.....	Do.
Shafsbury, Mich. (near)....	11	5 p. m.	100		5,000	Tornado.....	Church, schoolhouse and farm buildings damaged; trees uprooted.	Do.
Cowarts, Ala. (near).....	11	10 p. m.			5,000	do.....	Small buildings and timber wrecked; several persons injured.	Do.
Alabama (northern and central).	11				50,000	Winds.....	Character of damage not reported.....	Do.
Batesville, Ark. (near)....	11				1,000	do.....	Small buildings and fences damaged.....	Do.
Chicago, Tower Hill, Braceville and Napoleon, Ill.	11				35,000	do.....	Plate-glass windows broken; signs, wires, and light buildings damaged.	Do.
Fort Smith, Ark.....	11				2,000	do.....	Buildings, fences and overhead wires damaged.	Do.
Ohio.....	11			4		Destructive winds.	Many thousands of dollars damage; character of which was not reported.	Do.
Wisconsin (eastern counties).	11				3,000	Wind.....	Considerable minor property damage reported..	Do.

<sup>1</sup> "Mi." signifies miles instead of yards.

#### RIVERS AND FLOODS

By MONTROSE W. HAYES

[In charge River and Flood Division]

During the first seven months of 1931 the precipitation was below normal over most of the country east of the Rocky Mountains. This deficiency, immediately following the long period of drought in 1930, caused extremely low stages in most of the rivers of the Mississippi system and gave the lowest stages ever recorded at many gaging stations in a summer month. This unusually long period in which the precipitation was subnormal was followed by three months, beginning with August, 1931, in which it was nearly normal. In November there was more than the usual precipitation through most of the Mississippi system, and in a large part of

this area the amounts were as much as four times the normal for the month. In December, 1931, and January, 1932, it was also above normal in most of the Mississippi Valley, and much above normal during January in the Red and Arkansas Basins. In February, 1932, the amounts were above normal in portions of the Ohio Basin, and in most of the Mississippi Valley below Cairo.

Many of the rivers in the Southeastern States, the Gulf States, and in the eastern and southern parts of the Mississippi system rose rapidly in the late fall and early winter, and the interior rivers of Mississippi and Louisiana were in high flood for an unusually long time.

There were floods in the Vermilion, Big Sioux, and Floyd Rivers of Iowa and South Dakota, caused by the rapid melting of snow. In the Republican River of Nebraska and Kansas there was local flooding caused by ice gorges.

A noteworthy feature of the floods was the short interval between the ending of the long-continued dry weather and the beginning of rapid rises in the streams of much of the country in the drought-stricken area.

The following is a statement of losses caused by the floods of January and February. The amounts, of course, are largely estimates, but they have been collected by field officials of the Weather Bureau from sources that are considered reliable.

#### ST. LAWRENCE DRAINAGE

Suspension of business, including wages of employees:  
Maumee River (Indiana)..... \$1, 200

#### ATLANTIC SLOPE DRAINAGE

Tangible property totally or partially destroyed: <sup>1</sup>  
Roanoke River (North Carolina)..... 500  
Cape Fear River (North Carolina)..... 1, 000  
Total..... 1, 500

Prospective crops:  
Saluda River (South Carolina)..... 50  
Ocmulgee River (Georgia)..... 15, 000  
Oconee River (Georgia)..... 2, 000  
Altamaha River (Georgia)..... 20, 000  
Total..... 37, 050

Livestock and other movable property:  
Peedee River (South Carolina)..... 2, 100  
Catawba-Wateree River (South Carolina)..... 200  
Ocmulgee River..... 200  
Oconee River..... 100  
Altamaha River..... 500  
Total..... 3, 100

Suspension of business, including wages of employees:  
Peedee River..... 2, 500  
Catawba-Wateree River..... 2, 800  
Santee River..... 5, 475  
Ocmulgee River..... 7, 500  
Oconee River..... 2, 600  
Altamaha River..... 17, 500  
Total..... 38, 375

#### EAST GULF OF MEXICO DRAINAGE

Tangible property totally or partially destroyed: <sup>1</sup>  
Alabama River (Alabama)..... 4, 775  
Black Warrior River (Alabama)..... 10, 000  
Tombigbee River (Alabama-Mississippi)..... 4, 500  
Pascagoula River (Mississippi)..... 100  
Pearl River (Mississippi-Louisiana)..... 15, 200  
Total..... 34, 575

Matured crops:  
Black Warrior River..... 1, 000

Prospective crops:  
Tombigbee River..... 1, 800  
Pearl River..... 2, 000  
Total..... 3, 800

Livestock and other movable property:  
Alabama River..... 1, 000  
Black Warrior River..... 900  
Tombigbee River..... 3, 800  
Pearl River..... 500  
Total..... 6, 200

<sup>1</sup> Includes buildings, fences, factories, highways, bridges, railroads, etc.

#### Suspension of business, including wages of employees:

Alabama River..... \$8, 500  
Black Warrior River..... 300  
Tombigbee River..... 4, 000  
Pascagoula River..... 1, 000  
Pearl River..... 9, 950  
Total..... 23, 750

#### MISSISSIPPI SYSTEM

##### Upper Mississippi Basin

Prospective crops:  
Illinois River (Illinois)..... 2, 400

##### Missouri Basin

Tangible property totally or partially destroyed: <sup>1</sup>  
Vermilion River (South Dakota)..... 9, 500  
Big Sioux River (South Dakota-Iowa)..... 41, 025  
Floyd River (Iowa)..... 100  
Republican River (Nebraska-Kansas)..... 29, 850  
Grand River (Missouri)..... 10, 000  
Total..... 90, 475

Matured crops:  
Vermilion River..... 350  
Republican River..... 500  
Total..... 850

Prospective crops:  
Republican River..... 200  
Livestock and other movable property:  
Big Sioux River..... 1, 000  
Republican River..... 650  
Total..... 1, 650

##### Ohio Basin

Tangible property totally or partially destroyed: <sup>1</sup>  
Tygart River (West Virginia)..... 6, 000  
Kentucky River (Kentucky)..... 13, 000  
Barren River (Kentucky)..... 1, 500  
Green River (Kentucky)..... 700  
West Fork of White River (Indiana)..... 10, 100  
Wabash River (Indiana-Illinois)..... 3, 800  
Cumberland River (Tennessee)..... 1, 000  
North Fork of Holston River (Virginia)..... 2, 500  
Nolichucky River (Tennessee)..... 25, 225  
Elk River (Tennessee)..... 155  
Tennessee River..... 250  
Ohio River..... 32, 600  
Total..... 96, 830

Matured crops:  
Kentucky River..... 500  
Barren River..... 650  
Green River..... 500  
West Fork of White River..... 150  
Embarrass River (Illinois)..... 3, 000  
Wabash River..... 1, 000  
Cumberland River..... 700  
Ohio River..... 10, 430  
Total..... 16, 930

Prospective crops:  
Barren River..... 800  
West Fork of White River..... 1, 200  
White River..... 300  
Embarrass River..... 7, 000  
Wabash River..... 1, 100  
Cumberland River..... 300  
Nolichucky River..... 160  
Elk River..... 3, 350  
Tennessee River..... 800  
Ohio River..... 4, 100  
Total..... 19, 110

<sup>1</sup> Includes buildings, fences, factories, highways, bridges, railroads, etc.

## Livestock and other movable property:

Kentucky River	\$700
West Fork of White River	100
Cumberland River	1,500
Pigeon River (Tennessee)	250
Nolichucky River	10,000
Ohio River	700

Total.....13,250

## Suspension of business, including wages of employees:

Tygart River	3,000
Monongahela River (Pennsylvania)	5,000
Kentucky River	500
Barren River	1,000
Green River	1,250
West Fork of White River	1,900
Wabash River	19,900
Cumberland River	5,642
Elk River	575
Tennessee River	2,250
Ohio River	36,954

Total.....77,971

*White Basin*Tangible property totally or partially destroyed:<sup>1</sup>

Black River (Arkansas)	3,000
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## Matured crops:

Black River	9,750
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## Livestock and other movable property:

Black River	1,000
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## Suspension of business, including wages of employees:

Black River	1,000
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*Arkansas Basin*Tangible property totally or partially destroyed:<sup>1</sup>

Arkansas River (Arkansas)	5,200
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## Matured crops:

Arkansas River	2,600
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## Livestock and other movable property:

Arkansas River	50
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## Suspension of business, including wages of employees:

Arkansas River	300
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*Red Basin*Tangible property totally or partially destroyed:<sup>1</sup>

Sulphur River (Texas)	8,500
Cypress River (Texas)	5,000
Lake Bisteneau (Louisiana)	1,000
Red River (Texas-Louisiana)	21,600

Total.....36,100

## Matured crops:

Red River	34,500
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## Prospective crops:

Lake Bisteneau	4,000
Red River	71,100

Total.....75,100

## Livestock and other movable property:

Little River (Arkansas)	20
Sulphur River	1,500
Red River	15,922

Total.....17,442

<sup>1</sup> Includes buildings, fences, factories, highways, bridges, railroads, etc.

## Suspension of business, including wages of employees:

Sulphur River	\$6,500
Cypress River	1,250
Red River	4,000

Total.....11,750

*Lower Mississippi Basin*Tangible property totally or partially destroyed:<sup>1</sup>

St. Francis River (Missouri-Arkansas)	36,500
Ouachita River (Arkansas-Louisiana)	90,000

Total.....126,500

## Matured crops:

St. Francis River	50,000
Ouachita River	40,000

Total.....90,000

## Prospective crops:

Ouachita River	57,000
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## Livestock and other movable property:

Ouachita River	132,917
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## Suspension of business, including wages of employees:

St. Francis River	53,000
Ouachita River	21,000

Total.....74,000

*WEST GULF OF MEXICO DRAINAGE*Tangible property totally or partially destroyed:<sup>1</sup>

Neches River (Texas)	3,000
Sabine River (Louisiana-Texas)	1,500
Trinity River (Texas)	33,780

Total.....38,280

## Matured crops:

Trinity River	200
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## Prospective crops:

Sabine River	2,000
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## Livestock and other movable property:

Neches River	400
Sabine River	9,100
Trinity River	3,590

Total.....13,090

## Suspension of business, including wages of employees:

Sabine River	3,600
Trinity River	925

Total.....4,525

*PACIFIC SLOPE DRAINAGE*Tangible property totally or partially destroyed:<sup>1</sup>

Long Tom River (Oreg.)	100
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A report of the losses caused by the floods in the Tallahatchie, Yazoo, Mississippi, and Atchafalaya Rivers will be given in a later issue of the MONTHLY WEATHER REVIEW.

One person was drowned in the Cumberland River, and three were drowned in the St. Francis River.

<sup>1</sup> Includes buildings, fences, factories, highways, bridges, railroads, etc.

The estimated money value of property saved by warnings was as follows:

ST. LAWRENCE DRAINAGE	
Maumee River.....	\$4, 000
ATLANTIC SLOPE DRAINAGE	
Roanoke River.....	15, 000
Neuse River.....	2, 500
Cape Fear River.....	5, 000
Peedee River.....	30, 000
Congaree River.....	450
Catawba-Wateres River.....	31, 300
Santee River.....	10, 350
Savannah River.....	2, 750
Ocmulgee River.....	42, 500
Oconee River.....	30, 000
Altamaha River.....	50, 000
Total.....	219, 850
EAST GULF OF MEXICO DRAINAGE	
Alabama River.....	8, 000
Black Warrior River.....	22, 000
Tombigbee River.....	77, 800
Pascagoula River.....	4, 500
Pearl River.....	25, 000
Total.....	137, 300
MISSISSIPPI SYSTEM	
Upper Mississippi Basin	
Illinois River.....	10, 000
Missouri Basin	
Big Sioux River.....	19, 000
Ohio Basin	
Kentucky River.....	10, 000
Barren River.....	30, 000
Green River.....	3, 525
West Fork of White River.....	50, 500
East Fork of White River.....	50, 000
White River.....	1, 000
Wabash River.....	40, 200
Cumberland River.....	9, 000
Elk River.....	5, 600
Tennessee River.....	6, 000
Ohio River.....	161, 700
Total.....	367, 525
White Basin	
White River.....	1, 000
Arkansas Basin	
Arkansas River.....	2, 500
Red Basin	
Sulphur River.....	116, 000
Cypress River.....	3, 000
Red River.....	92, 500
Total.....	211, 500
Lower Mississippi Basin	
Ouachita River.....	141, 000
WEST GULF OF MEXICO DRAINAGE	
Sabine River.....	42, 500
Trinity River.....	57, 010
Total.....	99, 510

The following is a tabular statement of flood stages that occurred in January and February. In the cases in which an inundation had not dropped below flood

stage on or before February 29 the crest that has been entered in the table is the highest stage of January or February, and in some instances it may not be the actual crest for the entire flood.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ST. LAWRENCE DRAINAGE					
St. Joseph: Montpelier, Ohio.....	10	Jan. 3	Jan. 8	10.2	Jan. 3.
Maumee: Fort Wayne, Ind.....	15	Jan. 14	Jan. 15	10.1	Jan. 15.
		Jan. 23	Jan. 24	10.4	Jan. 24.
		Jan. 18	Jan. 18	15.1	Jan. 18.
ATLANTIC SLOPE DRAINAGE					
Chenango: Sherburne, N. Y.....	8	Feb. 12	Feb. 13	8.7	Feb. 12.
James: Columbia, Va.....	10	Feb. 6	Feb. 8	18.0	Feb. 6.
Roanoke:					
Weldon, N. C.....	31	Jan. 10	Jan. 12	37.3	Jan. 11.
Scotland Neck, N. C.....	23	do	Jan. 14	28.4	Jan. 13.
Williamston, N. C.....	9	Jan. 11	Jan. 22	11.2	Jan. 17.
		Feb. 7	Feb. 11	9.5	Feb. 9, 10.
Neuse:					
Neuse, N. C.....	15	Jan. 9	Jan. 13	17.0	Jan. 12.
Smithfield, N. C.....	14	do	Jan. 14	17.0	Do.
Cape Fear:					
Moncure, N. C.....	22	do	Jan. 10	24.0	Jan. 9.
Fayetteville, N. C.....	35	Jan. 10	Jan. 12	42.8	Jan. 11.
Elizabethtown, N. C.....	22	do	Jan. 15	30.9	Jan. 12.
Peedee:					
Cheraw, S. C.....	27	Jan. 9	Jan. 11	34.5	Jan. 10.
Mars Bluff Bridge, S. C.....	17	Jan. 11	Jan. 19	20.9	Jan. 15.
Poston, S. C.....	18	Jan. 15	Jan. 21	20.8	Jan. 17, 18.
Saluda:					
Pelzer, S. C.....	7	Dec. 31	Jan. 2	8.0	Jan. 1.
		Jan. 6	Jan. 10	9.6	Jan. 8.
Chappells, S. C.....	14	Jan. 7	Jan. 11	19.6	Jan. 9.
		Feb. 23	Feb. 22	14.0	Feb. 22.
Broad: Blairs, S. C.....	15	Jan. 1	Jan. 2	17.9	Jan. 2.
		Jan. 7	Jan. 10	20.2	Jan. 10.
Congaree: Columbia, S. C.....	15	Jan. 9	do	16.9	Do.
Catawba: Catawba, S. C.....	12	Jan. 8	Jan. 9	12.0	Jan. 9.
Wateres: Camden, S. C.....	24	do	Jan. 11	30.0	Jan. 9.
Santee:					
Rimmi, S. C.....	12	Jan. 3	Jan. 17	19.8	Jan. 14.
		Feb. 24	Feb. 29	13.6	Feb. 26.
Ferguson, S. C.....	12	Jan. 3	Jan. 25	14.0	Jan. 16.
		Feb. 24	Feb. 29	13.0	Feb. 28, 29.
Jamestown, S. C.....	12	Jan. 13	Jan. 23	18.0	Jan. 20.
		Jan. 2	Jan. 20	24.7	Jan. 11.
Savannah: Ellenton, S. C.....	14	Jan. 29	Feb. 11	19.2	Feb. 6.
		Feb. 15	Feb. 29	20.0	Feb. 25.
Ocmulgee:					
Macon, Ga.....	18	Feb. 4	Feb. 4	18.1	Feb. 4.
		Feb. 22	Feb. 22	18.0	Feb. 22.
Abbeville, Ga.....	11	Jan. 14	Jan. 17	12.2	Jan. 15.
		Feb. 29	Mar. 2	11.8	Mar. 1.
Oconee: Milledgeville, Ga.....	22	Jan. 9	Jan. 9	25.2	Jan. 9.
Altamaha: Charlotte, Ga.....	15	Feb. 4	Feb. 4	23.5	Feb. 4.
		Jan. 16	Jan. 19	15.8	Jan. 17.
EAST GULF OF MEXICO DRAINAGE					
Apalachicola: Blountstown, Fla.....	15	Jan. 9	Jan. 20	17.7	Jan. 11.
		Feb. 7	Feb. 9	15.9	Feb. 8.
		Feb. 25	Feb. 29	17.8	Feb. 26.
Choctawhatchee: Caryville, Fla.....	12	Jan. 16	Jan. 17	12.1	Jan. 16, 17.
Oostanaula: Resaca, Ga.....	22	Jan. 31	Feb. 5	23.1	Feb. 3.
Cocosa: Gadsden, Ala.....	20	Jan. 30	Feb. 9	24.0	Feb. 4, 5.
		Jan. 6	Jan. 6	25.8	Jan. 6.
Cahaba: Centerville, Ala.....	23	Jan. 30	Jan. 31	28.0	Jan. 30.
		Feb. 22	Feb. 23	24.0	Feb. 22.
Alabama:					
Montgomery, Ala.....	30	Feb. 23	Feb. 25	32.1	Feb. 24.
Selma, Ala.....	35	Feb. 24	Feb. 26	37.1	Feb. 25.
		Jan. 9	Jan. 9	35.6	Jan. 9.
Millers Ferry, Ala.....	35	Feb. 3	Feb. 8	36.6	Feb. 5.
		Feb. 22	Feb. 29	41.9	Feb. 26.
Black Warrior: Lock 10, Tuscaloosa, Ala.....	46	Jan. 7	Jan. 7	47.3	Jan. 7.
		Jan. 30	Feb. 1	52.1	Jan. 31.
		Feb. 15	Feb. 24	54.4	Feb. 18.
Tombigbee:					
Aberdeen, Miss.....	34	Jan. 15	Jan. 15	34.0	Jan. 15.
		Jan. 31	Feb. 6	37.1	Feb. 4.
		Feb. 17	Feb. 25	37.6	Feb. 23.
Columbus, Miss.....	25	Feb. 20	do	26.1	Do.
Lock 4, Demopolis, Ala.....	30	Jan. 7	Jan. 18	46.6	Jan. 11.
		Jan. 28	Mar. 9	50.1	Feb. 29.
Chickasawhay: Shubuta, Miss.....	26	Jan. 31	Jan. 31	26.0	Jan. 31.
		Jan. 8	Jan. 14	19.1	Jan. 10.
Pascagoula: Merrill, Miss.....	18	Feb. 1	Feb. 3	18.2	Feb. 2, 3.
		Feb. 25	Feb. 28	18.4	Feb. 27.
Pearl:					
Edinburg, Miss.....	20	Jan. 8	Jan. 8	20.4	Jan. 8.
		Feb. 22	Feb. 27	22.5	Feb. 25.
Jackson, Miss.....	22	Dec. 21	Feb. 10	28.7	Feb. 1, 2.
		Feb. 22	Feb. 29	29.1	Feb. 28, 29.
		Jan. 7	Jan. 8	18.8	Jan. 7.
Monticello, Miss.....	18	Jan. 24	Jan. 31	21.8	Jan. 25.
		Feb. 22	Feb. 25	19.3	Feb. 23.
		Jan. 7	Jan. 11	19.8	Jan. 8, 9.
Columbia, Miss.....	18	Jan. 17	Jan. 18	18.3	Jan. 17.
		Jan. 25	Feb. 4	22.7	Jan. 28.
		Feb. 23	Feb. 29	20.0	Feb. 25, 26.
West Pearl: Pearl River, La.....	13	Dec. 21	Feb. 20	15.9	Jan. 29-Feb. 1.
		Feb. 25	(1)	15.2	Feb. 26-29.

1 Continued into March.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM					
Upper Mississippi Basin					
Des Moines:	Feet			Feet	
Tracy, Iowa.....	14	Jan. 1	Jan. 4	16.7	Jan. 3
Ottumwa, Iowa.....	10	Jan. 2	Jan. 5	11.5	Jan. 3, 4
Illinois:					
Peru, Ill.....	14	Jan. 2	Feb. 5	16.9	Jan. 18
Henry, Ill.....	10	Feb. 12	Feb. 23	16.1	Feb. 13
Havana, Ill.....	10	Jan. 18	Jan. 30	10.8	Jan. 20, 21
Beardstown, Ill.....	14	Jan. 17	Feb. 6	15.0	Jan. 23-26
	14	Feb. 15	Feb. 23	14.2	Feb. 17-21
	14	Jan. 21	Feb. 4	15.0	Jan. 26
Missouri Basin					
Big Sioux: Akron, Iowa.....	12	Feb. 28	Mar. 7	18.0	Mar. 1
Republican: Concordia, Kans.....	8	Feb. 25	Feb. 25	8.1	Feb. 25
Grand:					
Gallatin, Mo.....	20	Jan. 1	Jan. 3	30.5	Jan. 2, 3
Chillicothe, Mo.....	18	do	Jan. 6	28.8	Jan. 2
Brunswick, Mo.....	12	Jan. 4	do	14.2	Jan. 5
Ohio Basin					
Tygart: Phillipi, W. Va.....	20	Feb. 4	Feb. 5	25.0	Feb. 4
Cheat: Rowlesburg, W. Va.....	12	do	do	13.8	Do.
Monongahela:					
Lock 15, Houlit, W. Va.....	22	Feb. 5	do	23.8	Feb. 5
Lock 7, Greensboro, Pa.....	30	do	do	35.8	Do.
Lock 4, Pennsylvania.....	31	do	do	33.4	Do.
Walhonding: Walhonding, Ohio.....	8	Jan. 18	Jan. 18	11.7	Jan. 18
		Jan. 23	Jan. 23	8.6	Jan. 23
		Jan. 18	Jan. 20	9.5	Jan. 19
Muskingum: Coshocton, Ohio.....	8	Jan. 24	Jan. 24	8.3	Jan. 24
Little Kanawha:					
Glenville, W. Va.....	23	Jan. 30	Jan. 31	26.0	Jan. 30
		Feb. 4	Feb. 5	27.8	Feb. 5
Creston, W. Va.....	20	Jan. 30	Jan. 31	22.0	Jan. 30
		Feb. 4	Feb. 5	21.4	Feb. 5
Elk: Clay, W. Va.....	18	do	do	26.6	Do.
Levisa Fork: Pikeville, Ky.....	35	Jan. 30	Jan. 30	40.0	Jan. 30
Scioto:					
La Rue, Ohio.....	11	Jan. 18	Jan. 18	11.8	Jan. 18
		do	Jan. 19	12.8	Jan. 19
Circleville, Ohio.....	10	Jan. 23	Jan. 25	11.4	Jan. 24
		Jan. 31	Jan. 31	10.7	Jan. 31
Chillicothe, Ohio.....	16	Jan. 20	Jan. 20	16.1	Jan. 20
Kentucky:					
Hazard, Ky.....	20	Jan. 30	Jan. 30	21.5	Jan. 30
Beattyville, Ky.....	30	Jan. 31	Jan. 31	36.5	Jan. 31
Frankfort, Ky.....	31	do	do	31.0	Do.
Barren: Bowling Green, Ky.....	20	Jan. 24	Jan. 26	24.2	Jan. 25
		Jan. 29	Feb. 3	34.0	Jan. 31
Green:					
Munfordville, Ky.....	28	Jan. 24	Jan. 27	32.0	Jan. 26
		Jan. 30	Feb. 3	30.7	Jan. 31
Lock 6, Brownsville, Ky.....	28	Jan. 24	Jan. 28	32.6	Jan. 26
		Jan. 29	Feb. 5	40.1	Feb. 1
Lock 4, Woodbury, Ky.....	33	Jan. 18	Jan. 18	33.3	Jan. 18
		Jan. 24	Feb. 8	47.1	Feb. 2
Lock 2, Rumsey, Ky.....	34	Jan. 15	Feb. 20	42.9	Feb. 8
West Fork:					
Elliston, Ind.....	19	do	Jan. 27	24.2	Jan. 22
		Jan. 6	Jan. 11	15.7	Jan. 9
Edwardsport, Ind.....	15	Jan. 14	Feb. 2	19.6	Jan. 23
East Fork:					
Seymour, Ind.....	10	Jan. 18	Jan. 19	12.5	Jan. 18
Williams, Ind.....	10	Jan. 20	Jan. 28	12.4	Jan. 23
Shoals, Ind.....	20	Jan. 18	Jan. 30	25.1	Jan. 24
White: Decker, Ind.....	18	Jan. 17	Feb. 4	24.1	Jan. 25
Wabash:					
Lafayette, Ind.....	13	Jan. 16	Jan. 21	17.3	Jan. 19
		Jan. 17	Jan. 22	20.3	Jan. 20
Covington, Ind.....	16	Jan. 25	Jan. 25	16.2	Jan. 25
Terre Haute, Ind.....	16	Jan. 19	Jan. 24	17.6	Jan. 23
Vincennes, Ind.....	14	Jan. 21	Jan. 30	16.8	Jan. 25
Mt. Carmel, Ill.....	16	Jan. 16	Feb. 4	23.8	Jan. 26
Cumberland:					
Williamsburg, Ky.....	22	Jan. 31	Feb. 2	25.0	Jan. 31
Burnside, Ky.....	50	Jan. 30	Feb. 1	53.2	Do.
Celina, Tenn.....	45	Feb. 1	Feb. 7	47.4	Feb. 5
Carthage, Tenn.....	40	Feb. 3	Feb. 10	48.8	Do.
Nashville, Tenn.....	40	Jan. 31	Feb. 12	48.2	Feb. 8
Clarksville, Tenn.....	46	do	Feb. 14	52.3	Feb. 10
Lock F, Eddyville, Ky.....	57	Feb. 3	Feb. 17	62.8	Feb. 12
North Fork: Mendota, Va.....	8	Jan. 30	Jan. 30	11.0	Jan. 30
		Feb. 3	Feb. 4	10.8	Feb. 4
Holston: Rogersville, Tenn.....	14	Feb. 4	do	16.0	Do.
		Jan. 30	Jan. 30	8.7	Jan. 30
Pigeon: Newport, Tenn.....	6	Feb. 3	Feb. 3	7.2	Feb. 3
		Feb. 13	Feb. 13	6.8	Feb. 13
Clinch:					
Spears Ferry, Va.....	18	Jan. 30	Jan. 31	21.2	Jan. 30
Clinton, Tenn.....	26	Feb. 1	Feb. 1	31.9	Feb. 1

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM—continued					
Ohio Basin—Continued					
Hiwassee: Charleston, Tenn.	22	Jan. 31	Jan. 31	22.0	Jan. 31.
		Jan. 30	do	17.6	Jan. 30.
Elk: Fayetteville, Tenn.	14	Feb. 2	Feb. 2	14.8	Feb. 2.
		Feb. 4	Feb. 4	14.1	Feb. 4.
		Feb. 17	Feb. 18	16.1	Feb. 18.
Tennessee:					
Chattanooga, Tenn.	30	Feb. 1	Feb. 1	30.4	Feb. 1.
		Feb. 7	Feb. 7	30.0	Feb. 7.
Bridgeport, Ala.	18	Feb. 1	Feb. 9	21.4	Feb. 3.
Widows Bar Dam, Ala.	17	Jan. 31	do	22.3	Do.
Guntersville, Ala.	25	Feb. 1	Feb. 10	30.8	Feb. 4.
Florence, Ala.	18	Feb. 2	do	19.6	Feb. 3, 4.
Riverton, Ala.	33	Feb. 1	Feb. 13	40.0	Feb. 5, 6.
		Feb. 17	Feb. 24	37.1	Feb. 19.
Savannah, Tenn.	39	Feb. 5	Feb. 11	39.9	Feb. 6-8.
		Feb. 3	Feb. 14	32.7	Feb. 6-10.
Johnsonville, Tenn.	31	Feb. 20	Feb. 20	31.1	Feb. 20.
Ohio:					
Louisville, Ky., upper gage	28	Feb. 4	Feb. 8	29.7	Feb. 5.
Louisville, Ky., lower gage	31	do	do	32.7	Do.
Dam 43, Evans Landing, Ind.	55	Feb. 5	Feb. 5	55.1	Do.
Dam 44, Leavenworth, Ind.	50	Feb. 3	Feb. 10	54.6	Feb. 6.
Dam 45, Addison, Ky.	45	Feb. 4	do	47.8	Do.
Dam 46, Owensboro, Ky.	38	Feb. 3	Feb. 12	40.9	Do.
Dam 47, Newburgh, Ind.	35	Jan. 19	Jan. 19	35.1	Jan. 19.
		Jan. 26	Feb. 15	42.7	Feb. 7.
Evansville, Ind.	35	Jan. 18	Jan. 21	36.0	Jan. 19.
		Jan. 25	Feb. 16	43.2	Feb. 7.
Dam 48, Cypress, Ind.	35	Jan. 27	do	42.8	Feb. 8.
Mount Vernon, Ind.	35	Jan. 19	Jan. 21	35.3	Jan. 20.
		Jan. 26	Feb. 18	43.1	Feb. 9.
Dam 49, Uniontown, Ky.	35	Jan. 20	Jan. 23	35.4	Jan. 21.
		Jan. 25	Feb. 18	43.0	Feb. 9.
Shawneetown, Ill.	33	Jan. 16	Feb. 20	45.1	Feb. 10, 11.
Dam 50, Fords Ferry, Ky.	32	Jan. 14	Feb. 22	46.4	Feb. 11.
Dam 51, Golconda, Ill.	38	Jan. 30	Feb. 19	43.9	Feb. 12.
Paducah, Ky.	39	do	Feb. 22	46.8	Feb. 12, 13.
Dam 52, Brookport, Ill.	35	Jan. 18	Feb. 25	46.7	Feb. 13.
Dam 53, Grand Chain, Ill.	38	do	Feb. 26	48.8	Feb. 12, 13.
Cairo, Ill.	40	Jan. 16	do	49.1	Feb. 14-17.
White Basin					
Black: Black Rock, Ark.	14	Jan. 17	Feb. 3	19.6	Jan. 18.
		Feb. 17	Feb. 19	15.8	Feb. 17.
Cache: Patterson, Ark.	9	Jan. 6	Feb. 8	11.0	Jan. 18, 19.
White:					
Batesville, Ark.	23	Jan. 24	Jan. 24	23.7	Jan. 24.
Newport, Ark.	20	Jan. 25	Jan. 27	26.7	Jan. 26.
		Jan. 8	Jan. 11	22.4	Jan. 9.
Georgetown, Ark.	22	Jan. 17	Feb. 6	24.8	Jan. 29, 30.
De Valls Bluff, Ark.	24	Jan. 18	do	25.7	Jan. 30, 31.
Clarendon, Ark.	30	Jan. 26	Feb. 5	30.4	Jan. 30-Feb. 2.
Arkansas Basin					
Petit Jean: Danville, Ark.	20	Jan. 6	Jan. 9	23.1	Jan. 7.
		Jan. 17	Jan. 20	22.6	Jan. 18.
		Jan. 23	Jan. 28	24.3	Jan. 24.
		Feb. 15	Feb. 21	24.3	Feb. 18.
Arkansas:					
Fort Smith, Ark.	22	Jan. 24	Jan. 24	22.0	Jan. 24.
Dardanelle, Ark.	20	Jan. 25	Jan. 25	20.2	Jan. 25.
Yancopin, Ark.	29	Jan. 8	(1)	40.2	Feb. 24, 25.
Red Basin					
Little: Whitecliffs, Ark.	26	Jan. 7	Jan. 10	27.6	Jan. 8.
		Jan. 25	Jan. 31	27.8	Jan. 26, 27.
Sulphur:		Feb. 19	Feb. 24	27.2	Feb. 20.
		Jan. 5	Jan. 10	27.9	Jan. 6.
		Jan. 12	Jan. 15	25.0	Jan. 13.
Ringo Crossing, Tex.	20	Jan. 17	Jan. 20	24.7	Jan. 18.
		Jan. 23	Jan. 28	27.0	Jan. 24.
		Feb. 17	Feb. 23	24.6	Feb. 18.
Finley, Tex.	24	Jan. 7	Feb. 2	29.0	Jan. 9.
		Feb. 20	Feb. 27	30.0	Feb. 22.
		Jan. 7	Jan. 14	23.6	Jan. 9.
Cypress: Jefferson, Tex.	18	Jan. 18	Jan. 10	18.4	Jan. 19.
		Jan. 30	Jan. 31	18.4	Jan. 31.
		Feb. 21	Feb. 25	20.9	Feb. 22.
Lake Bisteneau: Ninoek, La.	28	Jan. 25	Feb. 8	33.5	Jan. 30-Feb. 1.
		Feb. 20	Feb. 29	32.4	Feb. 26, 27.
Red:					
Index, Ark.	25	Jan. 24	Jan. 29	27.0	Jan. 27.
		Feb. 19	Feb. 23	27.4	Feb. 21.
		Jan. 10	Jan. 10	27.5	Jan. 10.
Fulton, Ark.	27	Jan. 19	Feb. 1	31.6	Jan. 26, 29.
		Feb. 20	Feb. 27	30.3	Feb. 22, 23.
Grand Ecree, La.	33	Jan. 12	Feb. 11	38.9	Feb. 2, 3.
		Feb. 21	Mar. 6	37.1	Feb. 27-29.
Alexandria, La.	36	Jan. 14	Feb. 16	43.6	Feb. 3-5.
		Feb. 22	Mar. 11	49.2	Mar. 2-4.
1 Continued into March.					

Continued into March.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI SYSTEM—continued					
Lower Mississippi Basin					
Big Lake: Big Lake Outlet, Ark.....	18	Jan. 26	Jan. 28	18.0	Jan. 26-28.
St. Francis:					
Chasola, Mo.....	22	Dec. 31 Jan. 17	Jan. 2 Jan. 20	24.6 25.0	Jan. 1. Jan. 18.
		Jan. 24	Jan. 24	23.1	Jan. 24.
Fisk, Mo.....	20	Dec. 31 Jan. 18	Jan. 5 Jan. 27	23.1 23.5	Jan. 3. Jan. 19.
St. Francis, Ark.....	18	Jan. 5 Feb. 22	Feb. 4 Feb. 23	21.6 18.2	Jan. 23. Feb. 22.
Marked Tree, Ark.....	17	Jan. 24	Feb. 12	18.2	Feb. 2-4.
Tallahatchie: Swan Lake, Miss.....	24	Dec. 15	(1)	35.0	Jan. 15.
Yazoo:					
Greenwood, Miss.....	35	Dec. 23	(1)	40.1	Jan. 19, 20.
Yazoo City, Miss.....	23	Dec. 31	(1)	32.0	Feb. 21.
Onachita:					
Arkadelphia, Ark.....	12	Jan. 5 Feb. 17	Jan. 7 Feb. 19	21.2 19.0	Jan. 6. Feb. 17.
Camden, Ark.....	30	Jan. 7 Feb. 18	Feb. 4 Feb. 26	38.0 36.0	Jan. 9. Feb. 21.
Monroe, La.....	40	Dec. 25	(1)	49.7	Feb. 2-4.
Black: Jonesville, La.....	50	Jan. 13	(1)	55.6	Mar. 5.
Mississippi:					
New Madrid, Mo.....	34	Jan. 30	Feb. 25	39.0	Feb. 17, 18.
Cottonwood Point, Mo.....	35	Feb. 7	Feb. 26	38.6	Feb. 19.
Memphis, Tenn.....	35	Feb. 4	Feb. 27	38.7	Do.
Helena, Ark.....	44	Jan. 31	(1)	49.2	Feb. 22.
Arkansas City, Ark.....	48	Jan. 28	(1)	53.4	Feb. 25, 26.
Greenville, Miss.....	42	Jan. 30	(1)	47.0	Feb. 26, 27.
Vicksburg, Miss.....	45	Jan. 28	(1)	51.9	Feb. 28, 29.
Natchez, Miss.....	46	Feb. 1	(1)	52.5	Feb. 29.
Angola, La.....	45	do.	(1)	51.7	Do.
Baton Rouge, La.....	35	do.	(1)	42.1	Do.
Plaquemine, La.....	31	do.	(1)	37.6	Do.
Donaldsonville, La.....	28	Feb. 4	(1)	33.0	Do.
Reserve, La.....	22	Feb. 8	(1)	24.8	Do.
New Orleans, La.....	17	Feb. 10	(1)	18.7	Do.
Atchafalaya Basin					
Atchafalaya:					
Simmesport, La.....	41	Feb. 3	(1)	47.0	Do.
Melville, La.....	37	Jan. 30	(1)	42.3	Do.
Atchafalaya, La.....	22	Dec. 27	(1)	24.8	Do.

<sup>1</sup> Continued into March.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
WEST GULF OF MEXICO DRAINAGE					
Neches:					
Rockland, Tex.....	22	Jan. 15	Jan. 16	22.5	Jan. 15.
		Jan. 20	Feb. 2	24.8	Jan. 30.
		Feb. 22	Mar. 4	26.8	Feb. 24.
Beaumont, Tex.....	7	Feb. 4	Feb. 5	7.2	Feb. 4.
		Feb. 29	Mar. 10	9.0	Mar. 4.
Sabine:					
Logansport, La.....	25	Jan. 7	Feb. 12	32.6	Jan. 21.
		Feb. 20	Mar. 16	35.5	Feb. 23.
Bon Wier, Tex.....	21	Jan. 16	Feb. 13	22.6	Feb. 1-3.
		Feb. 23	Mar. 10	22.7	Feb. 29.
Orange, Tex.....	4	Jan. 23	Feb. 13	4.8	Feb. 4-7.
		Feb. 22	Mar. 11	5.2	Mar. 4.
West Fork: Fort Worth, Tex.....	20	Jan. 16	Jan. 17	22.5	Jan. 16.
		Jan. 22	Jan. 23	30.0	Jan. 22.
		Feb. 16	Feb. 16	22.8	Feb. 16.
		Jan. 17	Jan. 18	8.7	Jan. 18.
Elm Fork: Carrollton, Tex.....	7	Jan. 22	Jan. 24	10.8	Jan. 23.
		Feb. 17	Feb. 19	9.5	Feb. 17.
		Feb. 23	Feb. 23	7.2	Feb. 23.
Trinity:					
Dallas, Tex.....	28	Jan. 6	Jan. 7	30.4	Jan. 6.
		Jan. 13	Jan. 13	30.0	Jan. 13.
		Jan. 17	Jan. 31	38.7	Jan. 23.
		Feb. 16	(1)	36.8	Feb. 18.
Trinidad, Tex.....	28	Jan. 6	Feb. 7	41.2	Jan. 29.
		Feb. 19	(1)	40.0	Feb. 24.
		Jan. 9	Jan. 20	43.0	Jan. 12.
Long Lake, Tex.....	40	Jan. 30	Feb. 10	44.0	Feb. 2.
		Feb. 21	Mar. 14	44.3	Feb. 25, 26.
Liberty, Tex.....	25	Jan. 9	(1)	27.8	Feb. 27-29.
Brazos: Waco, Tex.....	27	Feb. 19	Feb. 19	27.8	Feb. 19.
Guadalupe:					
Gonzales, Tex.....	17	Jan. 6	Jan. 6	18.0	Jan. 6.
Victoria, Tex.....	21	Jan. 8	Jan. 9	23.1	Jan. 9.
GULF OF CALIFORNIA DRAINAGE					
Salt: Phoenix, Ariz.....	5	Feb. 10	Feb. 12	9.9	Feb. 11.
Gila: Kelvin, Ariz.....	5	do.	Feb. 10	6.1	Feb. 10.
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Long Tom: Monroe, Oreg.....	10	Dec. 21	Jan. 4	13.0	Dec. 28.
		Jan. 17	Jan. 23	12.5	Jan. 20.
Yamhill: McMinnville, Oreg.....	35	Jan. 19	Jan. 20	36.7	Jan. 19.

<sup>1</sup> Continued into March.

## WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, F. A. YOUNG, temporarily in charge]

### NORTH ATLANTIC OCEAN

By F. A. YOUNG

**Pressure.**—A glance at Table 1 will give an idea of the most unusual distribution of pressure over the eastern section of the ocean during February, 1932. The positive departures of 0.77 inch, 0.75 inch, and 0.60 inch at Reykjavik, Lerwick, and Valencia, respectively, show that during the greater part of the month pronounced anticyclonic conditions prevailed over the region usually occupied by the Icelandic Low, while a negative departure of 0.30 inch at Horta indicates a weakening of the Atlantic HIGH. The weather conditions in the waters between the positions usually occupied by these two centers of action must have been most confusing to the seaman, as in place of the usual "westerlies," easterly winds prevailed during the greater part of the month over the eastern portion of the southern steamer lanes.

Over the western section of the ocean the average pressure conditions were more nearly normal as indicated by the comparatively small departures at stations on the American Atlantic and Gulf coasts, although there were the usual rapid changes of pressure from day to day at the Canadian stations.

TABLE 1.—Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, February, 1932

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Julianehaab, Greenland <sup>1</sup>	29.69	(1)	30.34	9	29.02	7
Reykjavik, Iceland <sup>1</sup>	30.31	+0.77	30.84	11	29.66	18
Lerwick, Shetland Islands <sup>1</sup>	30.47	+0.75	30.87	20	30.11	7
Valencia, Ireland <sup>1</sup>	30.50	+0.60	30.84	21	30.13	7
Lisbon, Portugal <sup>1</sup>	30.06	-0.04	30.42	1	29.53	29
Madeira <sup>1</sup>	29.96	-0.11	30.26	6	29.64	26
Horta, Azores <sup>1</sup>	29.85	-0.30	30.13	9	29.47	14
Belle Isle, Newfoundland <sup>1</sup>	29.70	-0.05	30.48	12	28.82	20
Halifax, Nova Scotia <sup>1</sup>	29.88	-0.03	30.44	2	29.24	18
Nantucket <sup>1</sup>	29.95	-0.09	30.55	1	28.96	5
Hatteras <sup>1</sup>	30.05	-0.11	30.66	1	29.47	28
Bermuda <sup>1</sup>	30.02	-0.10	30.44	2	29.22	29
Turks Island <sup>1</sup>	30.08	+0.01	30.20	* 1	29.86	29
Key West <sup>1</sup>	30.05	-0.02	30.29	1	29.84	28
New Orleans <sup>1</sup>	30.05	-0.04	30.48	1	29.76	21
Cape Gracias, Nicaragua <sup>1</sup>	29.94	-0.05	30.02	* 1	29.88	* 11

<sup>1</sup> All data based on s. m. observations only, with departures compiled from best available normals related to time of observations.

\* No normal available.

<sup>2</sup> Corrected 24-hour means, based on more than 1 observation.

<sup>3</sup> And on other dates.

**Cyclones and gales.**—The month of February is normally one of the stormiest of the year, and over the greater

part of the ocean, west of the thirtieth meridian, the number of days with gales, as well as their severity was fully as great as usual, the storm area in some cases extending as far south as the thirtieth parallel, while the American S. S. *Mobile City* reported a moderate gale not far from the Canal Zone.

Due to the persistent high-pressure area off the European coast, there were comparatively few gales over the eastern section of the steamer lanes, as they were not reported on more than two days in any 5° square in that region. As shown in table of gales, the Belgian S. S. *Mahagi*, while in 42° 40' N., 9° 35' W., reported a northeasterly wind, force 11, with a lowest barometer of 30.26 inches. This is most unusual, as it is seldom that an anticyclonic wind of such force is encountered, except at times during a "norther" in the Gulf of Mexico.

Charts VIII to XI cover the period from the 3d to the 6th inclusive, where the severest storms of the month occurred, although there were other periods of heavy weather, especially on the 23d.

**Fog.**—Fog was scarce over the greater part of the ocean, and the number of days on which it was reported in different localities is as follows: Over the Grand Banks, on 4 days; along the American coast between the thirty-

fifth and forty-fifth parallels, from 6 to 7 days; in the western section of the Gulf of Mexico, on 5 days; over the steamer lanes, east of the forty-fifth meridian, on 1 day in the 5° square between 50 to 55 N., and 35 to 40 W.; 1 day off the west coast of England.

According to the New York Maritime Register, there were a number of casualties during the month due to the weather. The Danish S. S. *Aggersund* was abandoned on February 28 while in 53° N., 42° W., the crew being taken aboard the Swedish M. S. *Blankenholm*. A dispatch from Antwerp on the 11th states that the American S. S. *City of Alton*, from Boston reports having shipped heavy seas during the voyage, the deckload being shifted and damage caused to fittings, life boats, etc. The Italian S. S. *Conte Biancamano* which arrived in New York from Naples on the 23d met with heavy weather during the voyage, and was placed in dry dock the same night. It was reported that several plates in the bottom would be treated, and also some rivets refastened.

**Waterspout.**—*El Occidente*, American steamship, Capt. E. S. Campbell, observer A. S. Pedersen, Galveston to New York. In latitude 29° 00' N., longitude 79° 45' W., 5.30 p. m. on the 20th saw two waterspouts about 5 miles west of position, 1 large and 1 medium size.

## OCEAN GALES AND STORMS, FEBRUARY, 1932

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN													
Boniface, Br. S. S.	Hull	Para	29 10 N	27 40 W	Feb. 1	6 a., 1.	Feb. 2	29.61	SW	W, 3.	WNW	WNW, 8.	S-W-WNW.
Comanche, Br. S. S.	London	Baytown	34 35 N	49 08 W	do.	Noon, 1.	do.	29.75	W	W, 1.	NW	WNW, 10.	W-NW-N.
Tuscarora, Br. S. S.	New Orleans	Belfast	35 25 N	50 57 W	Feb. 2	8 a., 2.	Feb. 3	29.93	NNW	NNW, 10.	NW	—, 10.	NNW-NW-NNW.
Illinois, Am. S. S.	Port Arthur	Amsterdam	42 10 N	30 50 W	do.	10 a., 2.	do.	29.83	ESE	ESE, 10.	ESE	ESE, 10.	Steady.
Wilhelm A. Riedemann, Danzig, M. S.	Falmouth	Cartagena	38 18 N	40 12 W	do.	4 p., 2.	do.	29.40	WSW	WSW, 7.	NW	NNW, 11.	Steady.
Mobile City, Am. S. S.	Canal Zone	London	12 04 N	77 04 W	do.	do.	Feb. 2	29.83	NNE	ENE, 7.	ENE	NE, 8.	NNE-ENE.
Savola, Ital. S. S.	Genoa	Philadelphia	35 00 N	51 00 W	do.	4 p., 3.	Feb. 4	29.71	NW	SW, 9.	SW	SW, 10.	—
Cameronia, Br. S. S.	Glasgow	New York	49 47 N	40 15 W	do.	11 a., 3.	do.	28.88	SSE	NNW, 9.	NW	NW, 10.	SE-W-NNW.
Hoxie, Am. S. S.	New York	Glasgow	50 35 N	33 00 W	do.	10 p., 3.	Feb. 3	28.92	SSE	S, 12.	WSW	S, 12.	SSE-S-WSW.
West Hika, Am. S. S.	Antwerp	Tampa	37 55 N	27 45 W	Feb. 3	Noon, 3.	Feb. 4	29.80	S	S, 5.	W	SSW, 10.	S-WNW.
Fred W. Weller, Am. S. S.	Baytown	Baltimore	34 48 N	75 18 W	Feb. 4	9 p., 4.	Feb. 5	29.66	SW	WSW, 8.	NW	WSW, 9.	W-NW.
Spur, Du. S. S.	Emden	Portland, Me.	34 36 N	46 32 W	do.	4 p., 4.	do.	29.64	SW	SW, 9.	NNW	SW, 10.	SW-WNW.
Nickerie, Du. S. S.	Madeira	Ouessant	35 38 N	14 37 W	do.	8 p., 4.	do.	30.09	NW	NW, 6.	NW	WNW, 8.	NW-N.
Atlantian, Br. S. S.	Norfolk	Liverpool	39 28 N	61 48 W	do.	10 a., 5.	Feb. 6	29.06	S	SW, 9.	NNW	—, 9.	SSW-NNW.
Cameronia, Br. S. S.	Glasgow	New York	45 10 N	56 45 W	Feb. 5	10 p., 5.	do.	29.32	SE	SE, 4.	NW	NW, 10.	E-Var-NNW.
Bremen, Ger. S. S.	New York	Cherbourg	42 10 N	53 10 W	do.	5 p., 5.	do.	29.01	SSE	SSE, 11.	SSW	S, 12.	SE-S.
Colombia, Du. M. S.	English Channel	Barbados	33 45 N	37 56 W	do.	10 a., 5.	Feb. 5	29.49	SSW	W, 9.	NNW	—, 9.	SW-W.
Europa, Ger. S. S.	Cherbourg	New York	45 08 N	43 47 W	Feb. 6	Noon, 6.	Feb. 7	29.28	E	S, 9.	W	—, 11.	—
Frederik VIII, Dan. S. S.	Oslo	do.	46 20 N	52 40 W	Feb. 5	6 a., 6.	Feb. 6	28.61	E	SE, 7.	W	WNW, 11.	SE-S-NNW.
Gateway City, Am. S. S.	Liverpool	Mobile	34 00 N	35 40 W	Feb. 6	4 p., 6.	Feb. 7	29.84	S	S, 7.	W	SSE, 8.	S-SW.
Hoxie, Am. S. S.	New York	Glasgow	54 22 N	30 11 W	do.	8 a., 6.	Feb. 6	29.00	SSE	S, 7.	N	S, 9.	SSE-S-N.
Nevada, Dan. S. S.	do.	Copenhagen	54 13 N	32 32 W	do.	4 a., 7.	Feb. 8	29.08	SE	SE, 10.	SSE	SE, 10.	—
Lepanto, Br. S. S.	Hull	Boston	44 37 N	45 20 W	Feb. 9	10 p., 9.	Feb. 9	29.65	SW	S, 10.	SW	S, 10.	SW-S-W.
Mopan, Br. S. S.	Santa Marta	Rotterdam	46 30 N	23 15 W	Feb. 10	11 p., 10.	Feb. 11	29.66	NNE	NNE, 7.	ENE	NE, 8.	NNE-E.
City of Bagdad, Br. S. S.	New York	Port Said	39 58 N	62 00 W	Feb. 11	4 p., 11.	Feb. 12	29.90	S	SSE, 8.	S	—, 8.	—
Deli, Du. S. S.	Sabang	London	43 08 N	9 23 W	do.	Noon, 11.	Feb. 13	—	ENE	E, 3.	E	E, 9.	Steady.
Pologne, Fr. S. S.	Bordeaux	San Juan	28 48 N	42 57 W	Feb. 12	3 a., 13.	do.	—	ESE	ENE, 8.	NNE	ENE, 8.	—
Europa, Ger. S. S.	New York	British Channel	47 51 N	31 16 W	Feb. 14	2 a., 15.	Feb. 15	29.46	E	SSE, 10.	SSE	SSE, 11.	—
Monifore, Ital. S. S.	Palermo	Pensacola	31 38 N	23 25 W	do.	—, 15.	Feb. 17	29.77	SE	S, 8.	WNW	WSW, 8.	—
Liberty Glo, Am. S. S.	Antwerp	Charleston	34 16 N	59 15 W	Feb. 16	10 a., 16.	do.	29.63	W	W, 7.	N	NW, 9.	W-NW.
Shickshinny, Am. S. S.	Manchester	do.	35 00 N	51 41 W	do.	Noon, 16.	Feb. 21	29.12	SSW	W, 6.	NW	WNW, 11.	—
Escambia, Ital. S. S.	Genoa	Pensacola	27 40 N	51 30 W	do.	2 a., 17.	Feb. 18	29.63	WNW	WNW, 7.	W	NW, 8.	NW-NNW.
Dordrecht, Du. S. S.	Baytown	Manchester	38 10 N	66 32 W	Feb. 18	6 p., 18.	Feb. 20	29.55	NW	NW, 8.	NNW	NW, 9.	NW-NNW.
Titus, Du. S. S.	Puerto Barrios	Amsterdam	39 30 N	52 00 W	do.	4 p., 18.	Feb. 19	28.84	SSW	S, 9.	W	S, 9.	S-SW-W.
Oranlian, Br. S. S.	Liverpool	Boston	47 47 N	36 22 W	do.	5 p., 18.	Feb. 18	29.35	ESE	ESE, 8.	SW	S, 9.	ESE-SW.
Exeter, Am. S. S.	Marseille	New York	37 12 N	41 18 W	do.	3 p., 19.	Feb. 20	29.44	SW	S, 8.	SW	W, 10.	S-W.
Jean Jadot, Belg. S. S.	New York	Antwerp	39 54 N	54 14 W	do.	Noon, 20.	do.	29.39	NW	NNW, 4.	NNW	NW, 9.	NW-NNW.
Quaker City, Am. S. S.	Boston	Dundee	51 55 N	41 41 W	Feb. 20	7 a., 20.	Feb. 22	29.23	E	E, 8.	SE	ESE, 10.	—
Waukegan, Am. S. S.	Havre	New York	43 52 N	46 00 W	Feb. 21	Noon, 21.	Feb. 21	29.02	N	N, 8.	NNW	NNW, 10.	NE-N-NNW.
Sagaporack, Am. S. S.	Hoyanger, Norway	Portland, Me.	45 45 N	44 20 W	do.	6 p., 21.	Feb. 22	28.65	E	W, 9.	W	WNW, 11.	SE-S-W-WNW.
Monifore, Ital. S. S.	Palermo	Pensacola	29 00 N	42 20 W	do.	—, 21.	do.	29.69	W	W, 9.	NW	—, 9.	Steady.
Mahagi, Belg. S. S.	Lobito Bay	Rotterdam	42 40 N	9 35 W	do.	11 a., 21.	do.	30.26	NE	NE, 8.	NNE	NE, 11.	Do.
West Selene, Am. S. S.	Santos	Boston	23 50 N	65 30 W	Feb. 22	6 p., 22.	Feb. 23	29.73	SW	SW, 10.	WNW	SW, 10.	SW-WSW.
Exmalia, Am. S. S.	Casablanca	New York	36 22 N	38 10 W	Feb. 21	4 a., 22.	Feb. 23	29.49	S	WSW, 8.	NNW	—, 9.	NE-N.
Hoxie, Am. S. S.	Avonmouth	Baltimore	44 48 N	50 30 W	Feb. 19	1 p., 23.	Feb. 23	28.70	SE	NE, 10.	N	N, 11.	NE-N.
Europa, Ger. S. S.	British Channel	New York	44 24 N	47 31 W	Feb. 22	4 p., 23.	do.	28.42	SE	SSW, 12.	W	—, 12.	S-SW.

## OCEAN GALES AND STORMS, FEBRUARY, 1932—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN—Con.													
Blommersdijk, Du. S. S.	Rotterdam	Boston	44 42 N	45 50 W	Feb. 23	3 p. 23	do	28.64	ESE	S, 12	W	—, 12	S-SW.
Brabeholm, Swed. S. S.	Newcastle-on-Thyne	Philadelphia	52 48 N	36 47 W	Feb. 22	6 p. 24	Feb. 25	29.10	SSE	SSW, 10	WSW	SSW, 10	
Virginia, Hond. S. S.	Boston	Jamaica	29 20 N	72 48 W	Feb. 26	5 p. 26	Feb. 26	29.43	E	SW, 3	NNW	ESE, 8	S-NNW.
Binnendijk, Du. S. S.	English Channel	New York	46 14 N	40 32 W	do	7 a. 26	do	29.02	SSE	S, 8	WSW	W, 9	SSE-S-W.
El Almirante, Am. S. S.	New Orleans	do	27 50 N	79 40 W	Feb. 27	6 a. 27	Feb. 29	30.05	NW	NW, 7	NNW	N, 9	
Examalia, Am. S. S.	Casablanca	do	37 50 N	05 12 W	Feb. 29	4 a. 29	Mar. 2	29.23	N	N, 8	NW	N, 11	Steady.
Cerintus, Br. S. S.	Rouen	Port Arthur	32 28 N	60 59 W	do	8 p. 29	Mar. 1	29.12	S	W, 7	WNW	NNW, 9	
Shirvan, Br. S. S.	Constantza	Ardrossan	47 09 N	7 57 W	Feb. 28	4 a. 29	do	29.67	ENE	ENE, 8	ENE	ENE, 9	Steady.
Macedonier, Belg. S. S.	Rio de Janeiro	Antwerp	33 01 N	14 05 W	Feb. 29	3 p. 29	do	29.25	W	WNW, 9	W	WNW, 9	
NORTH PACIFIC OCEAN													
San Diego Maru, Jap. M. S.	Yokohama	San Luis	40 22 N	163 37 E	Jan. 30	5 a. 1	Feb. 2	28.89	SE	ESE	S	WNW, 10	16 pts.
Kentucky, Am. S. S.	Hong Kong	San Francisco	43 33 N	176 10 E	Feb. 1	2 p. 1	do	29.77	SE	SSE, 8	SE	SSE, 9	
Adm. Farragut, Am. S. S.	San Francisco	Portland	44 30 N	124 36 W	Feb. 2	4 p. 2	do	29.80	SE	SE, 9	SE	SE, 10	SE-ESE.
Olympia Maru, Jap. M. S.	Sydney	Yokohama	32 55 N	140 20 E	Feb. 3	2 p. 3	Feb. 3	29.57	SSW	NW, 9	W	NW, 9	W-NW.
Fernwood, Nor. M. S.	Manila	San Pedro	36 20 N	145 30 E	do	11 p. 3	Feb. 4	29.20	SE	NNE, 12	NNE	NNE, 12	S-NNE.
M. H. Whittier, Am. S. S.	San Pedro	Honolulu	31 37 N	130 13 W	do	10 p. 3	do	29.40	SSE	SSE, 7	W	SSE, 9	S-SSE-SE.
Steel Age, Am. S. S.	Hawaii	Vancouver	19 25 N	139 30 W	do	11 p. 3	do	29.76	S	S, 8	S	S, 8	Steady.
Lebec, Am. S. S.	Portland	San Pedro	42 30 N	124 50 W	do	2 p. 3	do	29.82	S	S, 10	SSE	S, 10	Do.
Golden Peak, Am. S. S.	Longview	Yokohama	41 56 N	140 05 W	do	8 a. 3	Feb. 5	29.84	WNW	WNW, 7	NNE	N, 9	
Canad. Winner, Br. S. S.	Panama	Victoria	13 53 N	95 12 W	Feb. 4	11 p. 4	do	29.90	N	NNE, 7	NE	NNE, 8	
San Julian, Am. S. S.	Balboa	San Pedro	16 00 N	94 30 W	Feb. 5	4 p. 5	Feb. 6	29.85	N	N, 8	N	N, 8	N-NW.
Pres. Taft, Am. S. S.	Victoria	Yokohama	51 43 N	142 30 W	Feb. 8	12 p. 8	Feb. 9	29.42	W	WNW, 8	WSW	WNW, 9	WSW-WNW.
Chief Caplano, Br. S. S.	Port Alberni	do	50 15 N	180 00	do	6 p. 8	Feb. 10	28.84	E	SSE, 8	W	W, 10	SSE-SW.
Oakbank, Br. M. S.	Kobe	San Pedro	31 09 N	143 23 E	Feb. 10	11 a. 10	Feb. 11	29.77	SSW	SSW, 8	N	NNE, 9	
Pres. Taft, Am. S. S.	Victoria	Yokohama	51 58 N	169 03 W	Feb. 11	4 a. 11	Feb. 12	29.24	SE	SW, 9	W	SW, 9	SE-SW-W.
Bintang, Du. M. S.	Rangoon	Los Angeles	34 00 N	120 40 W	Feb. 12	8 a. 12	do	29.69	SSW	SSW, 4	NNW	NW, 10	S-SW-W.
Pres. Coolidge, Am. S. S.	San Francisco	Honolulu	S. F. Light Vessel		Feb. 13	Noon, 13	Feb. 14	29.76	NNW	NNW, 8	N	NNW, 9	NNW-N.
Maul, Am. S. S.	Honolulu	San Francisco	37 00 N	124 17 W	Feb. 15	6 p. 15	Feb. 16	29.67	NNW	NNW, —	N	N, 8	
M. H. Whittier, Am. S. S.	do	do	27 00 N	149 10 W	Feb. 14	8 a. 14	do	29.36	NE	E, 10	SE	E, 10	NE-E-SE.
Golden Cross, Am. S. S.	Los Angeles	New Zealand	28 12 N	148 48 W	Feb. 16	2 p. 16	do	29.56	ENE	SE, 10	SSE	SE, 10	SE-SSE.
Canad. Winner, Br. S. S.	Panama	Victoria	39 56 N	124 32 W	Feb. 15	9 p. 15	Feb. 17	29.76	N	N, 8	N	N, 9	
Silverview, Br. M. S.	San Pedro	Yokohama	34 30 N	152 30 W	Feb. 16	do	do	29.50	S	SSW, 10	WSW	SSW, 10	S-SSW-WSW.
Melville Dollar, Am. S. S.	Philippines	Los Angeles	40 34 N	159 54 E	do	do	do	29.45	E	SSE, 10	S	SSW, 10	2 pts.
Pres. Taft, Am. S. S.	Victoria	Yokohama	43 19 N	153 22 E	do	9 a. 17	Feb. 18	28.47	Calm	SW, 10	NW	SSW, 11	SSW-SW.
Columbia Maru, Jap. M. S.	Yokohama	Seattle	45 23 N	164 52 E	do	Mdt., 17	do	29.07	SE	SSE, 5	SE	SE, 9	ESE-SE.
Pres. Madison, Am. S. S.	do	Victoria	46 48 N	164 43 E	do	do	Feb. 19	29.00	SE	SE, 4	E	SSE, 9	
Pres. Coolidge, Am. S. S.	San Francisco	Honolulu	23 40 N	153 50 W	Feb. 17	2 p. 17	Feb. 17	29.63	SE	SE, 8	SW	SSE, 10	SE-SW.
Kurama Maru, Jap. M. S.	Yokohama	Los Angeles	46 30 N	161 20 W	do	Noon, 19	Feb. 21	30.06	ENE	ENE, 10	NNE	ENE, 10	ENE-E.
Northwestern, Am. S. S.	Seward	Seattle	58 10 N	135 00 W	Feb. 20	2 a. 20	Feb. 20	29.66	N	N, 7	NNW	NNW, 10	N-NNW.
Columbia Maru, Jap. M. S.	Yokohama	do	48 15 N	178 55 E	do	4 p. 21	Feb. 21	29.92	E	ENE, 7	NE	E, 9	E-ENE-NE.
Melville Dollar, Am. S. S.	Philippines	Los Angeles	44 37 N	178 32 E	do	do	Feb. 23	29.70	ENE	ENE	N	NE, 9	2 pts.
Golden Peak, Am. S. S.	Columbia River	Yokohama	34 06 N	151 11 E	Feb. 21	3 p. 21	Feb. 22	29.52	WSW	W, 12	NW	W, 12	WSW-W.
Seattle, Am. S. S.	Manila	San Francisco	36 57 N	151 19 E	do	3 p. 21	Feb. 23	29.28	NW	NW, 11	W	WNW, 11	N-NW-WNW.
Illinois, Am. S. S.	Columbia River	Yokohama	33 20 N	143 15 E	Feb. 25	3 a. 26	Feb. 27	29.42	ESE	SW, 9	NNW	WNW, 10	S-SW-W.
Point Sur, Am. S. S.	Tampa	San Diego	14 18 N	94 45 W	Feb. 26	6 a. 27	do	29.88	NW	N, 8	NNE	N, 8	Steady.
Pres. Coolidge, Am. S. S.	Honolulu	Yokohama	30 05 N	152 10 E	do	Mdt., 26	do	29.59	W	W, 8	NNW	W, 9	W-WNW.
Golden Wall, Am. S. S.	Hong Kong	San Francisco	38 22 N	156 43 E	do	8 a. 27	Feb. 29	29.23	S	SW, 7	NW	W, 11	SW-NW.
Golden Sun, Am. S. S.	Otaru	do	47 38 N	166 15 E	Feb. 27	do	do	28.46	E	E, 7	NE	NE, 9	
Point Sur, Am. S. S.	Tampa	San Diego	19 30 N	105 30 W	Feb. 29	5 a. 29	Mar. 1	29.87	NW	NW, 8	NNE	NW, 8	Steady.
SOUTH PACIFIC OCEAN													
Crown City, Am. M. S.	Long Beach	Capetown	47 40 S	80 00 W	Feb. 3	9 a. 3	Feb. 5	29.26	NNW	NNW, 8	NW	WNW, 9	NNW-WNW.
SOUTH ATLANTIC OCEAN													
Maria De Larrinaga, Br. S. S.	North Shields	Bahia Blanca	Off Bahia Blanca		Feb. 11	8 a. 11	Feb. 11	29.70	SSE	SSE, 7	SSW	SW, 9	SSE-S-SW.

1 Barometer uncorrected.

## NORTH PACIFIC OCEAN

By WILLIS E. HURD

**Atmospheric pressure.**—During February, 1932, the same conditions of alternating high and low pressure in the Aleutian region persisted as in January. On several days the anticyclones crossing the higher latitudes of the ocean were abnormally well built-up. On the 18th and 19th St. Paul, in Bering Sea, had the extraordinarily high barometric reading of 30.90 inches. Curiously enough, at about the same time in the North Atlantic, the near vicinity of the Iceland Low was dominated by an anticyclone of similar magnitude, the maximum pressure at Lerwick, Shetland Islands, being 30.87 inches, on the 20th. As few of the cyclones of the month were deep about the Aleutian Islands, the consequence was that the Aleutian low on the average was about three-tenths of an inch shallower than normal to the westward of the Alaskan Peninsula. The average center of the depression lay over the Gulf of Alaska, mean barometer at Kodiak, 29.76 inches.

The anticyclone off the middle American coast was weaker than normal for the month, while that off the Asiatic coast was in the same degree more highly developed than the average.

In low latitudes of the Pacific pressures were abnormally low. This was particularly noticeable at Honolulu, where the average barometer of 29.92 was below the normal by as much as 0.13 inch. Except in the vicinity of the Hawaiian Islands, however, there was an unusual lack of cyclonic development this month in Pacific equatorial waters.

TABLE 1.—Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean and adjacent waters, February, 1932, at selected stations

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow <sup>1</sup>	30.11	-0.01	30.84	20	29.42	25
Dutch Harbor <sup>1</sup>	29.92	+0.32	30.70	19	28.90	15
St. Paul <sup>1</sup>	29.94	+0.29	30.90	18	28.82	12
Kodiak <sup>1</sup>	29.76	+0.14	30.38	3	28.98	8
Juneau <sup>1</sup>	29.78	-0.14	30.38	3	28.86	9
Tafeloh Island <sup>1</sup>	30.00	0.00	30.30	16	29.26	9
San Francisco <sup>1</sup>	30.03	-0.07	30.33	24	29.55	8
Maratani <sup>1</sup>	29.95	-0.05	30.06	25	29.84	12
Honolulu <sup>1</sup>	29.92	-0.13	30.14	27	29.62	21
Midway Island <sup>1</sup>	29.91	-0.08	30.18	25	29.46	22
Guam <sup>1</sup>	29.85	-0.06	30.00	11	29.74	3
Manila <sup>1</sup>	29.92	-0.04	30.02	26	29.78	3
Naha <sup>1</sup>	30.12	+0.07	30.28	17	29.86	21
Chichishima <sup>1</sup>	30.01	+0.03	30.18	12	29.78	5
Nemuro <sup>1</sup>	29.95		30.38	1	29.44	29

<sup>1</sup> Data based on 1 daily observation only, with departures computed from best available normals related to time of observation.

<sup>2</sup> A. m. and p. m. observations.

<sup>3</sup> Data for 1 to 5 days missing.

<sup>4</sup> And on other dates.

<sup>5</sup> Corrected to 24-hour mean.

**Winds and storms in Asiatic waters.**—As a result of the strong seaward extension of the anticyclones from Asia, the northerly monsoon current was brisk to high in its velocities on several days between the Yellow and China Seas.

The severest cyclones of the month, so far as reports indicate, originated south or west of Japan and, moving east or northeast, acquired their greatest intensity in the region between latitudes 30° and 45° N., longitudes 145° and 165° E. Here the winds rose locally to forces of 11 or 12 on the 3d, 17th, 21st, and 28th. The storms seem quickly to have died out or abated after reaching their maxima of strength. The cyclone occasioning the severe

gale of the 17th originated near southwestern Japan on the 15th. By the 17th, when central south of the Kuril Islands, it had become of great depth. On this date the American S. S. *President Taft*, passed through its calm center near 43° N., 153° E., with barometer depressed to 28.47 inches, which is the lowest reading on record for the entire North Pacific this month.

**Gales elsewhere on the ocean.**—Considering the ocean as a whole, despite the severity of the weather on several days over the western part of the middle and northern trans-Pacific routes, February was less stormy than any of the preceding three months. East of the one hundred and eightieth meridian no gales of record exceeded 10 in force, but these, as well as lesser gales, occurred locally on several dates, and for the most part are noted sufficiently in the accompanying table of gales.

The period of most general storminess was that of the 15th to 17th. In addition to the heavy gales then occurring east of Japan, northerly gales of force 9 were blowing off the middle and upper California coasts on the 15th and 16th, being continuations of gales which began there on the 13th and 14th. In midocean a great trough of low pressure, which extended from high latitudes well into the tropics, caused northeast and southeast gales of force 9-10 on the 15th to 17th near to and northeast of the Hawaiian Islands, and southerly gales of similar force on the 16th and 17th over a wide reach of the sea extending thence northward as far as the forty-fifth parallel.

Other and isolated high winds of special note were: A south gale of force 8 on the 3d, near 19° N., 140° W.; a low-latitude locality where winds from this direction are rare, even in the summer season, unless occasioned by infrequent tropical cyclones; a southeast gale of force 10 on the 2d and 3d on the Oregon coast; and fresh norther gales in the Gulf of Tehuantepec on the 4th, 5th, and 27th.

**Winds at Honolulu.**—The prevailing wind direction at Honolulu continued from the east, but, owing to the rather frequent appearance of depressions in the neighborhood, there was interspersed a fair sprinkling of southerly konas. The highest velocity at the station was 31 miles from the west on the 21st.

**Fog.**—Vessels reported fog west of the one hundred and eightieth meridian on only one day. East of this meridian, between 30° and 52° north latitude, the majority of 5° squares had from one to five days with fog, except along the Oregon and California coasts, where it was more frequent, the place of maximum occurrence being within short distances of San Francisco. Along the eastern half of the San Francisco-Honolulu route fog was quite general from the 23d to 27th.

## SEA-SURFACE TEMPERATURE OBSERVATIONS, FEBRUARY, 1932

By GILES SLOCUM

Table 1 shows the average surface temperatures of the Caribbean Sea and the Straits of Florida for February, 1932. These figures are based upon about 80 per cent of the observations which will eventually become available. They are, therefore, preliminary, rather than final values. The final, revised figures, computed from complete data, will be given at a later date.

## CARIBBEAN SEA

The temperature of the Caribbean Sea was somewhat higher this month than the 13-year February mean (1920-1932). On the basis of the mean monthly temperature values, computed from the 146 months since

January, 1920, February, 1932, was the twenty-fourth consecutive month having average or above average temperature.

The extreme warmth<sup>1</sup> in the Caribbean, which prevailed in December, 1930, and during the first nine months of 1931, was, however, at an end. February, 1932, was the fifth successive month with temperatures not more than 0.5° above the average, and the departure, 0.2°, of this month from the 13-year mean was that of an essentially normal month rather than of a particularly warm one, since approximately two months out of three may be expected to have greater temperature anomalies than 0.2°.

#### STRAITS OF FLORIDA

The Straits of Florida showed a temperature situation quite different from that in the Caribbean. In the straits, this was the warmest February in the 13 years of record. Both the second and the third quarters of this month (the 8th to the 14th and the 15th to the 21st) were warmer than any previous February quarter-month during the entire period treated, and the temperature anomaly of February, 1932, as a whole, was greater than that of any previous month from 1920 to date.

December, 1931, January, 1932, and February, 1932, taken together, constitute a period in which the surface temperatures in the Straits of Florida were as remarkably higher than normal as were those in the Caribbean Sea through most of 1931. The straits area was warmer during each of these three months than it had ever been

<sup>1</sup> Cf. Summary of Sea-Surface Temperature Data for 1931, MONTHLY WEATHER REVIEW, Vol. 60: 35.

before during the same months since the beginning of 1920. In addition, the temperature departures of 1.9°, 1.8°, and 2.1°, respectively, from the 12 or 13 year December, January, and February means were each greater than that for any month in the 12 years preceding the beginning of this warm period in 1931-32.

These extreme conditions paralleled in magnitude of temperature anomaly and in uniqueness, if not in duration, the unprecedented thermal condition in the Caribbean shortly before. The periods of extreme warmth in the two areas, were, however, not contemporaneous. The abnormally high temperatures in the Caribbean were at an end before the abnormally high temperatures appeared in the straits, and, during the early winter months, the nearly seasonable temperatures in the Caribbean and the remarkably high temperatures in the straits were in strong contrast.

TABLE 1.—Preliminary mean sea-surface temperatures (°F.) in the Caribbean Sea and Straits of Florida, February, 1932

Quarter	Period	Caribbean Sea			Straits of Florida		
		Mean (°F.)	Departure from 13-year mean (1920-1932)	Change from preceding month	Mean (°F.)	Departure from 13-year mean (1920-1932)	Change from preceding month
I.....	Feb. 1-7.....	78.8	+0.1	-----	76.2	+1.3	-----
II.....	Feb. 8-14.....	78.4	0.0	-----	77.0	+1.6	-----
III.....	Feb. 15-21.....	79.1	+0.5	-----	77.4	+2.7	-----
IV.....	Feb. 22-29.....	78.9	+0.3	-----	76.6	+1.9	-----
	Month.....	78.8	+0.2	-0.8	76.8	+2.1	+0.1

The temperature of the Caribbean Sea was somewhat higher this month than the 13-year February mean (1920-1932). On the basis of the mean monthly temperature values computed from the 145 months since

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The severe cyclone of the month, so far as reports indicate, originated south or west of Japan and moving east or northeast, acquired their greatest intensity in the region between latitudes 30° and 45° N., longitudes 145° and 165° E. Here the winds rose locally to forces of 11 or 12 on the 3d, 17th, 21st, and 23d. The storm seems quickly to have died out or abated after reaching their maxima of strength. The cyclone occasioning the severe

The temperature of the Caribbean Sea was somewhat higher this month than the 13-year February mean (1920-1932). On the basis of the mean monthly temperature values computed from the 145 months since

## CLIMATOLOGICAL TABLES

## CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

*Condensed climatological summary of temperature and precipitation by sections, February, 1932*

[For description of tables and charts, see REVIEW, January, p. 37]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
Alabama	58.1	+9.5	Thomasville	86	10	Valley Head	-22	1	In.	In.	Gadsden	9.19	Union Springs	1.21
Arizona	48.1	+0.1	2 stations	90	28	Fort Defiance	-15	4	4.97	-0.34	Bright Angel Ranger Station	13.33	Snowflake	0.21
Arkansas	52.0	+8.7	3 stations	86	10	Sunset	9	4	2.92	+1.75	Prescott	8.14	Gravette	1.14
California	44.7	-2.5	Bettevavia	95	28	Soda Springs	-28	3	4.72	+1.42	Squirrel Inn	22.07	Greenland Ranch	0.05
Colorado	32.2	+4.7	Lamar	83	29	Hermit	-32	3	4.09	-0.09	Cumbres	12.33	4 stations	0.00
Florida	68.9	+8.4	Venus	92	18	Garniers (near)	31	5	1.13	+0.17	De Funiak Springs	4.64	Bartow	0.08
Georgia	57.9	+9.4	2 stations	87	18	Blairsville	18	1	1.18	-1.89	Newman	8.02	Darien	0.05
Idaho	23.1	-4.9	Lewiston	66	26	Felt	-34	4	3.73	-1.25	Roland	10.66	Salmon	0.08
Illinois	38.6	+9.2	White Hall	83	10	Sycamore	2	1	1.63	-0.13	Cairo	4.43	Rockford	0.41
Indiana	39.4	+9.2	2 stations	81	10	Rochester	5	1	1.39	-0.52	Forest Reserve	3.45	Wabash	0.79
Iowa	28.9	+6.9	Keokuk (No. 2)	74	10	3 stations	-16	3	1.71	-0.81	Lacona	2.27	Tipton (near)	0.08
Kansas	40.4	+6.7	4 stations	84	28	Cawker City	-7	4	0.83	-0.35	Fredonia	1.95	Ashland	T.
Kentucky	46.7	+10.1	Williamstown	82	10	Williamstown	15	1	0.71	-0.30	Harlan	7.42	Anchorage	1.88
Louisiana	62.6	+9.1	5 stations	88	28	Robeline	25	5	3.36	-0.09	Logansport	10.96	Houma	1.68
Maryland-Delaware	40.5	+6.5	Cumberland, Md.	88	11	Friendsville, Md.	8	1	4.48	+0.31	Oakland, Md.	3.77	Hancock (city), Md.	1.44
Michigan	27.5	+7.5	Monroe	68	11	Sidnaw	-22	23	2.35	-0.73	Whitefish Point	5.16	Iron River (near)	0.81
Minnesota	14.8	+3.0	Beardsley	63	27	Big Falls	-35	1	1.71	+0.03	Mizpah	4.49	Artichoke Lake	0.03
Mississippi	59.1	+9.6	4 stations	86	19	3 stations	25	5	0.68	-0.12	Water Valley	8.95	Biloxi	1.96
Missouri	42.4	+10.0	2 stations	83	10	Maryville	-3	4	6.19	+1.30	Sikeston	5.25	Eldon	0.23
Montana	23.8	+2.7	Columbus	79	27	Malta	-33	2	1.41	-0.70	Heron	7.51	Baker	0.00
Nebraska	30.7	+5.1	Falls City	80	27	Ashland	-14	1	0.60	-0.04	Orleans	1.90	2 stations	T.
Nevada	29.8	-6.7	Logandale	85	27	2 stations	-26	3	0.69	-0.03	Marlette Lake	5.29	Mina	0.00
New England	24.2	+1.6	Waterbury, Conn.	56	26	Van Buren, Me.	-31	12	1.33	+0.26	Portland, Me.	4.48	Danforth, Me.	0.72
New Jersey	35.9	+3.6	3 stations	69	26	2 stations	-4	12	2.19	-0.98	Culvers Lake	3.23	Tuckerton	1.08
New Mexico	41.4	+3.1	Carlsbad	85	27	Gavilan	-26	4	2.16	-1.54	Chama	4.00	Isidore	0.13
New York	27.6	+5.5	Fredonia	73	11	Stillwater Reservoir	-22	21	0.89	+0.19	Taberg	3.89	Chazy	0.45
North Carolina	49.7	+6.9	Newbern	85	11	Mount Mitchell	8	4	2.27	-0.52	Andrews	9.83	Kinston	1.41
North Dakota	13.6	+3.4	Pettibone	69	28	3 stations	-31	1	3.10	-0.97	Hillsboro	1.06	2 stations	0.00
Ohio	38.0	+9.4	Chillicothe	79	11	5 stations	8	1	0.35	-0.14	Dam No. 28	2.99	Canfield	0.60
Oklahoma	49.9	+8.2	3 stations	88	9	Miami	8	4	1.27	-1.12	Tishomingo	5.95	Kenton	0.25
Oregon	31.1	-4.3	2 stations	79	26	Seneca	-49	14	1.90	+0.67	Crossett	11.02	Paisley	0.03
Pennsylvania	35.3	+7.2	Hyndman	83	11	Gouldsboro	-8	25	1.83	-1.31	Hollisterville	4.24	Newell	0.62
South Carolina	54.3	+6.7	4 stations	83	11	2 stations	20	1	1.64	-1.33	Blackville	6.40	Garnett	1.09
South Dakota	21.7	+2.3	2 stations	72	27	do	-25	3	3.74	-0.52	Hot Springs	1.55	8 stations	T.
Tennessee	50.3	+9.2	3 stations	80	10	Rugby	15	1	0.30	-0.32	Elkmont	9.94	Clarksville	3.54
Texas	58.3	+7.3	Blanco	97	7	Dalhart	10	1	6.07	+1.74	Nacogdoches	9.50	2 stations	0.00
Utah	28.9	-1.3	St. George	78	28	Woodruff	-33	4	3.20	+1.41	Alton	7.95	Lucin	0.14
Virginia	45.3	+7.6	Roanoke	87	11	Emory	9	1	1.78	+0.48	Emory	6.17	Quantico	1.21
Washington	31.8	-2.6	2 stations	72	26	Newport	-26	2	2.80	-0.35	Big Four	31.29	2 stations	T.
West Virginia	41.6	+8.3	Moorefield	86	11	Bayard	7	1	5.62	+1.34	Pickens	7.35	New Cumberland	0.79
Wisconsin	21.4	+4.7	2 stations	66	125	Iron River	-32	1	3.22	+0.54	Blair	2.87	Solon Springs	0.24
Wyoming	23.9	+1.7	Nine Mile Creek (near)	74	27	Riverside	-40	15	0.59	-0.18	Bechler River	4.18	Barnum	0.00
Alaska (January)	-2.3	-7.0	2 stations	48	17	Tanana	-60	18	1.33	+0.13	Ketchikan	16.30	McKinley Park	0.15
Hawaii	68.3	-0.2	Pahala	93	22	Kanalohuluhulu	42	15	2.74	+0.45	Puu Kukui (upper)	83.00	Puuwaawaa	1.76
Porto Rico	72.7	-0.7	San German	98	22	Guineo Reservoir	40	2	22.03	+17.80	Maunabo	2.96	San Lorenzo (farm)	0.00

1 Other dates also.

TABLE 1.—Climatological data for Weather Bureau stations, February, 1932

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind				Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month				
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. +2	Departure from normal	Maximum	Date	Mean minimum	Date	Mean	Greatest daily range	Mean wet thermometer	Mean temperature of dew point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity									
																							Miles per hour						Direction	Date		
New England	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	In.	In.	Days	Miles	°	Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	0-10	In.	In.	
Eastport	76	67	85	29.85	29.94	-0.04	19.8	-1.7	44	13	27	-2	1	12	29	18	73	2.46	-1.0	15	9,438	nw.	32	nw.	9	11	3	15	6.0	19.5	3.6	
Greenville, Me.	1,070	6	62	28.72	29.94	-0.05	14.0	-1.0	42	13	23	-11	1	5	33	21	61	1.70	-0.8	10	5,535	se.	29	nw.	8	11	6	12	22.8	17.0		
Portland, Me.	103	82	117	29.84	29.97	-0.05	24.8	-1.0	48	13	32	-8	24	18	33	21	61	4.48	-0.8	14	6,882	n.	29	nw.	18	14	4	11	5.2	26.4	2.7	
Concord	289	70	79	29.66	29.99	-0.05	24.1	-1.2	48	13	32	0	25	16	32	21	61	2.57	-0.4	8	4,534	nw.	25	w.	13	13	5	11	4.9	24.3	3.7	
Burlington	403	11	48	29.55	30.00	-0.03	21.4	-2.0	52	12	29	-7	25	14	33	21	61	1.19	-0.4	14	7,907	s.	38	s.	17	6	8	15	6.8	13.8	1.0	
Northfield	576	12	60	29.00	29.99	-0.05	19.8	-3.4	53	12	29	-14	25	10	38	17	80	1.33	-1.0	12	5,714	n.	27	s.	17	3	14	12	6.9	17.3	5.2	
Boston	125	106	105	29.83	29.98	-0.05	30.6	-1.8	55	13	38	11	25	23	25	27	20	67	1.74	-1.8	9	5,348	nw.	21	nw.	5	8	8	13	6.3	10.8	0.0
Nantucket	12	14	90	29.94	29.95	-0.09	33.1	-2.4	51	12	39	16	21	27	24	30	76	1.00	-1.9	11	10,505	nw.	56	ne.	5	10	5	14	6.3	0.7	0.5	
Block Island	26	11	46	29.93	29.96	-0.10	33.3	-2.9	49	8	39	15	16	28	25	32	79	2.25	-1.5	10	12,386	nw.	51	w.	1	12	4	13	5.7	1.6	T.	
Providence	160	215	251	29.80	29.98	-0.07	30.8	-1.8	53	12	38	12	16	24	26	27	20	64	1.76	-2.0	9	8,618	nw.	40	nw.	23	12	4	13	5.6	7.8	0.0
Hartford	159	122	122	29.80	29.98	-0.08	30.6	-1.8	53	12	38	12	16	23	25	27	20	64	1.76	-1.8	9	8,618	nw.	40	nw.	23	12	4	13	5.6	7.8	0.0
New Haven	106	74	153	29.88	30.00	-0.07	33.0	-4.0	54	13	40	15	16	29	23	29	74	2.51	-1.6	10	6,478	n.	31	n.	4	11	8	10	5.7	5.4	0.0	
Middle Atlantic States							39.9	+6.6									69	2.03	-1.3										6.2			
Albany	97	107	115	29.90	30.01	-0.05	29.1	+5.0	55	12	37	9	25	22	27	26	72	1.80	-0.8	11	5,655	s.	25	se.	17	10	7	12	6.1	10.5	T.	
Binghamton	871	10	84	29.04	29.99	-0.09	30.4	+6.4	59	26	39	5	21	22	32	28	72	1.78	-0.6	19	4,871	nw.	23	nw.	18	3	8	18	8.2	6.0	0.0	
New York	314	414	454	29.65	30.00	-0.08	36.0	+4.7	58	8	43	17	16	29	27	32	24	65	2.38	-1.6	13	11,354	nw.	51	nw.	18	6	12	11	6.4	2.2	0.0
Belleville	1,050	5	36	28.86	30.00	-0.03	33.1	-0.7	64	26	43	11	23	23	36	29	75	1.17	-0.6	10	5,238	w.	34	w.	13	6	5	18	7.2	1.7	0.0	
Harrisburg	374	94	104	29.60	30.01	-0.08	38.0	+7.8	64	26	46	20	1	30	31	32	25	64	1.35	-1.7	9	5,827	nw.	32	w.	13	7	13	9	6.0	1.6	0.0
Philadelphia	114	123	367	29.90	30.03	-0.07	39.6	+5.7	64	26	47	23	1	33	27	34	26	51	1.58	-1.8	9	8,849	nw.	43	nw.	5	8	8	13	6.0	T.	0.0
Reading	325	81	103	29.67	30.03	-0.08	36.9	+8.1	62	26	44	18	1	30	28	32	25	64	1.00	-1.9	9	5,595	nw.	27	nw.	18	8	8	13	6.5	0.8	0.0
Scranton	805	72	103	29.15	30.04	-0.04	32.4	+5.1	59	11	41	10	21	24	28	29	73	3.03	-0.1	14	5,375	nw.	34	nw.	4	4	15	10	6.1	6.1	T.	0.0
Atlantic City	52	37	172	29.90	30.03	-0.08	39.0	+5.9	60	12	47	20	21	32	22	28	69	2.38	-1.2	8	5,827	nw.	46	nw.	5	5	11	13	6.1	T.	0.0	
Cape May	17	13	49	29.98	30.00	-0.06	40.0	+5.9	50	12	47	20	21	31	24	36	72	2.77	-0.6	6	5,827	nw.	46	nw.	5	5	11	13	6.1	T.	0.0	
Sandy Hook	22	10	55	29.98	30.00	-0.06	36.4	+5.3	53	13	42	21	21	31	20	33	30	79	1.61	-2.3	10	10,191	nw.	44	nw.	19	9	10	10	5.5	1.3	0.0
Trenton	190	159	183	29.80	30.02	-0.08	36.8	+6.1	63	26	45	18	16	29	29	32	26	60	1.51	-1.9	8	7,467	nw.	43	nw.	5	7	7	15	6.7	1.3	0.0
Baltimore	123	100	215	29.89	30.03	-0.08	42.8	+7.4	74	26	51	21	1	35	38	36	29	62	2.06	-1.4	9	7,388	sw.	40	sw.	13	7	9	13	6.0	T.	0.0
Washington	112	62	85	29.91	30.04	-0.07	42.9	+7.6	76	11	52	22	1	34	39	36	28	61	2.46	-0.9	11	5,435	nw.	30	nw.	4	8	8	13	6.0	T.	0.0
Cape Henry	18	8	54	30.01	30.03	-0.06	48.6	+7.4	82	11	56	29	1	42	31	44	39	75	2.43	-0.9	9	8,630	sw.	40	n.	20	9	8	12	5.9	0.0	0.0
Lynchburg	681	153	188	29.30	30.05	-0.06	47.8	+7.5	82	11	58	23	24	38	38	40	34	63	1.25	-2.0	9	5,480	w.	30	nw.	4	11	8	10	5.1	0.5	0.0
Norfolk	91	170	205	29.95	30.05	-0.06	49.4	+6.7	80	11	57	30	1	42	28	43	37	69	2.15	-1.2	10	8,424	se.	42	nw.	4	9	7	13	6.1	0.0	0.0
Richmond	144	11	52	29.89	30.05	-0.06	46.2	+6.6	81	11	56	24	24	36	40	36	74	1.66	-1.6	10	8,665	sw.	26	nw.	4	4	12	13	6.7	T.	0.0	
Wytheville	2,304	49	55	27.63	30.04	-0.08	43.2	+8.1	72	11	52	21	1	34	29	37	31	67	2.74	-0.3	11	8,957	w.	34	w.	4	8	12	9	5.4	T.	0.0
South Atlantic States							55.7	+7.8									73	2.66	-1.2										5.8			
Asheville	2,253	89	104	27.70	30.00	-0.04	47.3	+8.8	80	10	58	20	1	37	39	40	35	70	2.81	-0.5	11	6,421	nw.	31	nw.	4	12	9	8	4.9	0.0	0.0
Charlotte	779	55	62	29.22	30.07	-0.05	51.5	+7.6	75	11	61	31	1	42	35	45	40	69	2.52	-1.8	11	6,414	sw.	25	sw.	4	11	6	12	5.7	0.0	0.0
Greensboro	886	6	56	29.10	30.07	-0.05	47.0	+7.8	78	11	57	26	1	37	41	41	36	75	2.58	-1.8	11	5,851	sw.	31	nw.	4	11	6	15	6.4	0.0	0.0
Hatteras	11	5	50	29.05	30.05	-0.06	54.0	+6.8	72	12	60	39	21	45	20	42	82	2.43	-1.8	14	9,238	se.	43	nw.	5	10	9	10	6.0	0.0	0.0	
Raleigh	376	103	146	29.65	30.06	-0.05	51.0	+7.8	80	11	60	30	24	42	35	44	37	64	2.84	-1.2	10	6,001	sw.	32	nw.	4	13	3	13	5.8	0.0	0.0
Wilmington	72	73	106	29.99	30.08	-0.04	55.9	+8.0	77	11	65	33	1	47	29	49	44	74	1.93	-1.4	11	6,512	sw.	33	sw.	5	8	9	12	5.6	0.0	0.0
Charleston	48	11	92	30.02	30.07	-0.05	60.0	+7.6	78	10	67	42	5	53	25	54	51	79	1.17	-1.9	10	7,480	sw.	27	nw.	28	10	3	16	6.3	0.0	0.0
Columbia, S. C.	351	41	57	29.69	30.08</																											

TABLE 1.—Climatological data for Weather Bureau stations, February, 1932—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind				Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month			
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. + 2	Departure from normal	Maximum	Date	Mean minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity							Date		
																							Miles per hour								Direction	
Ohio Valley and Tennessee	ft.	ft.	ft.	in.	in.	in.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	in.	in.		Miles							0-10	in.	in.		
							44.8	+5.7									69	2.90	-0.5									6.0				
Chattanooga	702	190	215	29.24	30.06	-0.07	52.4	+8.3	77	10	62	30	5	43	35	46	39	65	5.81	+0.8	13	6,269	sw.	35	s.	11	9	9	11	5.7	0.0	0.0
Knoxville	995	102	111	29.00	30.07	-0.05	50.4	+8.6	76	11	59	26	1	41	35	44	38	67	5.76	+1.1	13	5,232	sw.	35	s.	11	11	7	11	5.3	0.0	0.0
Memphis	399	78	86	29.63	30.06	-0.05	53.8	+9.5	77	10	62	30	4	46	30	48	43	70	6.37	+0.9	11	6,007	sw.	25	nw.	4	10	9	10	5.6	0.0	0.0
Nashville	546	168	191	29.60	30.09	-0.03	51.3	+9.7	76	10	61	27	5	42	40	45	40	71	5.80	+1.5	11	7,000	s.	34	s.	11	10	8	11	5.3	0.0	0.0
Lexington	989	193	230	29.00	30.09	-0.02	44.6	+9.2	75	10	53	21	1	36	33	33	33	3.01	-0.7	8	9,386	sw.	43	w.	11	15	3	11	4.7	0.0	0.0	
Louisville	625	188	234	29.48	30.07	-0.04	46.0	+9.0	78	10	55	23	1	37	31	40	34	66	2.85	-0.8	7	7,797	s.	40	s.	11	10	6	13	5.8	0.0	0.0
Evansville	431	76	116	29.68	30.06	-0.05	46.2	+9.9	79	10	54	24	1	38	29	41	36	72	2.03	-1.3	7	7,051	sw.	35	sw.	11	10	8	11	5.6	0.0	0.0
Indianapolis	822	194	230	29.13	30.04	-0.06	39.6	+8.5	73	10	48	18	1	32	32	35	30	69	1.47	-1.4	6	8,091	sw.	37	sw.	11	9	7	13	6.1	0.0	0.0
Royal Center	736	11	55	29.21	30.03	-0.02	35.2	-----	67	10	44	14	1	27	37	37	30	69	1.74	-0.7	9	8,188	sw.	30	w.	11	4	10	15	6.9	1.5	0.0
Terre Haute	575	96	129	29.41	30.04	-0.04	41.2	-----	73	10	50	19	1	33	33	37	31	71	1.31	-1.4	7	8,865	nw.	31	s.	11	10	6	13	5.9	0.1	0.0
Cincinnati	627	11	51	29.36	30.06	-0.04	42.6	+9.8	76	10	51	15	1	34	34	37	31	69	1.79	-1.3	8	8,117	sw.	37	sw.	11	11	6	13	6.0	0.0	0.0
Columbus	822	216	230	29.15	30.04	-0.05	39.6	+8.9	70	11	48	16	1	32	33	35	30	71	0.82	-1.9	8	8,560	s.	41	sw.	11	6	8	15	6.9	0.4	0.0
Dayton	899	137	173	29.07	30.05	-0.02	40.3	+7.7	77	10	48	19	1	33	31	35	30	70	1.42	-1.3	8	8,908	sw.	46	nw.	11	7	9	13	6.1	0.6	0.0
Elkins	1,947	59	67	27.98	30.05	-0.02	39.3	+7.7	77	11	50	14	1	29	35	35	29	70	4.82	+1.6	12	5,194	w.	31	w.	11	4	9	16	7.1	0.0	0.0
Parkersburg	637	77	82	29.40	30.06	-0.04	42.6	+8.4	77	11	62	19	1	33	37	37	29	64	1.58	-1.6	9	5,184	sw.	28	sw.	11	11	4	14	5.7	0.0	0.0
Pittsburgh	842	353	410	29.11	30.04	-0.05	38.3	+6.0	75	11	46	13	1	30	29	34	28	68	0.82	-1.9	11	8,277	w.	46	w.	11	4	8	17	7.2	1.5	0.0
Lower Lake Region							31.7	+6.7									75	1.73	-0.8								7.3					
Buffalo	767	243	280	29.11	29.96	-0.10	31.3	+7.0	68	11	38	14	1	24	32	28	25	80	2.21	-0.8	16	12,390	w.	54	w.	11	4	4	21	7.4	12.6	0.0
Canton	448	10	61	29.47	29.98	-0.05	20.4	+2.4	57	11	29	-7	24	12	39	25	25	80	2.05	-0.3	17	6,402	s.	34	w.	12	7	8	14	6.5	17.9	2.8
Ithaca	836	74	100	29.03	29.98	-0.05	30.4	+5.9	58	26	38	3	21	22	32	27	22	72	1.67	-0.4	18	8,255	nw.	31	nw.	18	2	7	20	8.2	15.2	0.0
Oswego	335	71	85	29.60	29.98	-0.08	28.8	+4.9	57	12	36	5	21	22	33	26	21	75	2.12	-0.7	14	8,778	s.	31	n.	4	2	6	10	8.2	16.6	1.0
Rochester	523	66	102	29.40	29.99	-0.07	30.8	+5.2	70	11	38	12	16	24	31	27	23	74	2.77	0.0	21	6,684	w.	30	sw.	12	5	5	19	7.4	25.3	0.3
Syracuse	596	65	79	29.53	29.99	-0.08	29.6	+5.8	61	11	37	7	16	22	35	26	24	75	2.69	-0.1	19	5,745	w.	25	nw.	18	3	8	18	8.0	20.7	0.8
Erle	714	130	166	29.20	29.99	-0.08	34.0	+7.1	72	11	41	16	1	27	32	31	26	74	1.16	-1.5	14	10,473	sw.	49	sw.	11	5	8	16	7.0	3.0	0.0
Cleveland	762	267	337	29.16	30.00	-0.07	35.8	+8.4	73	11	43	16	1	28	35	32	29	69	1.10	-1.5	12	10,904	w.	47	w.	11	4	6	19	7.9	4.1	0.0
Sandusky	629	5	67	29.30	30.00	-0.07	36.0	+8.6	69	11	43	14	1	29	37	31	26	71	1.06	-1.2	13	7,336	sw.	35	sw.	11	3	8	18	7.5	3.5	0.0
Toledo	628	205	243	29.32	30.02	-0.05	34.6	+7.3	67	11	42	12	1	27	35	31	26	71	1.29	-0.6	12	9,572	sw.	50	sw.	11	8	6	16	6.2	4.2	0.0
Fort Wayne	856	100	119	29.07	30.02	-0.05	35.3	+9.5	66	11	42	13	1	28	35	33	29	78	0.80	-1.6	8	7,547	sw.	34	s.	11	8	4	17	6.5	1.9	0.0
Detroit	730	218	288	29.19	30.00	-0.06	33.0	+7.7	62	20	40	11	1	26	30	31	27	81	1.81	-0.4	12	7,982	sw.	35	sw.	11	6	8	15	6.0	9.5	0.0
Upper Lake Region							25.8	+6.5									79	1.60	-0.3								7.1					
Alpena	609	13	89	29.26	29.95	-0.08	25.1	+7.1	57	11	32	6	14	18	24	23	20	79	1.73	0.0	14	8,779	nw.	35	nw.	8	2	13	14	7.3	8.2	0.0
Escanaba	612	64	60	29.27	29.96	-0.10	20.8	+5.4	45	11	30	-6	1	12	33	19	16	81	1.38	-0.2	11	7,067	nw.	28	nw.	8	8	7	14	6.1	12.9	0.5
Grand Haven	632	64	89	29.28	29.99	-0.06	30.9	+5.7	60	11	38	13	1	24	27	25	25	82	1.15	-1.1	9	9,295	nw.	41	w.	8	1	5	23	8.5	1.4	0.0
Grand Rapids	707	70	244	29.20	29.99	-0.06	31.8	+8.1	64	11	39	13	23	24	36	25	24	75	1.16	-1.2	11	9,325	sw.	51	sw.	11	2	10	17	7.6	4.2	0.0
Houghton	668	64	99	29.18	29.94	-0.11	18.6	+4.8	48	27	-6	20	10	37	26	24	73	3.65	+1.8	17	7,427	w.	42	w.	12	1	5	23	8.6	31.2	7.3	
Lansing	878	6	88	29.01	29.98	-0.02	30.2	+7.3	60	26	38	9	1	22	36	28	26	86	1.74	-0.2	11	7,923	sw.	35	sw.	11	4	10	15	6.8	6.0	0.0
Ludington	637	60	66	29.26	29.97	-0.07	29.0	+5.5	57	11	35	10	14	23	25	27	23	78	1.66	-0.4	15	8,747	w.	40	sw.	11	2	10	17	7.5	2.6	0.0
Marquette																																

TABLE 1.—Climatological data for Weather Bureau stations, February, 1932—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Snow, sleet, and ice on ground at end of month																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max., + mean min., +2	Departure from normal	Maximum	Date	Mean minimum	Date	Mean maximum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean thermometer dew point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction		Maximum velocity																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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Billings	3,140	5					26.7	+4.9												0.81																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														

<sup>1</sup> Observations taken bihourly.<sup>1</sup> Pressure not reduced to mean of 24 hours.

TABLE 2.—Data furnished by the Canadian Meteorological Service, February, 1932

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. +2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	Inches	Inches	Inches	° F.	° F.	° F.	° F.	° F.	° F.	Inches	Inches	Inches
Cape Race, N. F.	99				19.3		25.6	13.0	38	-9	3.48		25.8
Sydney, C. B. I.	48	29.79	29.84	-0.06	15.9	-3.4	25.0	6.8	41	-8	3.57	+1.48	51.5
Halifax, N. S.	88	29.76	29.87	-0.08	20.0	-2.4	27.6	12.4	50	-4	3.53	-1.63	17.0
Yarmouth, N. S.	65	29.77	29.85	-0.14	24.0	-1.8	30.5	17.6	44	4	4.94	+0.77	28.0
Charlottetown, P. E. I.	38	29.79	29.83	-0.12	14.6	-3.0	21.6	7.7	41	-4	2.97	-0.09	23.9
Chatham, N. B.	28	29.78	29.82	-0.14	10.9	-1.6	22.5	-0.7	46	-21	1.17	-1.99	11.1
Father Point, Que.	20	29.91	29.94	-0.04	8.6	-2.9	16.9	0.3	44	-16	1.44	-0.77	14.0
Quebec, Que.	296	29.64	29.98	-0.01	11.2	-0.6	18.7	3.6	42	-13	2.77	-0.50	23.5
Doucet, Que.	1,236				0.8		16.4	-14.8	45	-47	1.82		16.2
Montreal, Que.	187	29.74	29.96	-0.06	17.9	+3.4	24.3	11.6	48	-4	3.14	+0.07	21.8
Ottawa, Ont.	236	29.71	29.90	-0.03	17.6	+5.9	26.1	9.2	47	-7	2.60	-0.09	15.9
Kingston, Ont.	285	29.66	29.90	-0.05	24.9	+7.1	32.8	17.1	47	0	2.39	-0.15	14.4
Toronto, Ont.	379	29.55	29.98	-0.06	29.6	+8.1	35.9	23.2	51	9	2.76	+0.15	13.4
Cochrane, Ont.	930				6.0		16.0	-4.0	44	-28	2.23		20.5
White River, Ont.	1,244	28.50	29.87	-0.15	6.4	-6.2		-7.0	40	-42	2.76	+1.24	20.6
Southampton, Ont.	656	29.21	29.94	-0.08	23.7	+6.8	34.4	18.9	59	1	3.92	+1.02	23
Parry Sound, Ont.	688	29.22	29.95	-0.06	21.5	+7.2	29.0	13.5	47	-8	3.59	+0.67	15.8
Port Arthur, Ont.	644	29.19	29.93	-0.12	13.8	+7.4	22.4	5.2	48	-16	1.12	+0.22	7.7
Winnipeg, Man.	700	29.12	29.99	-0.11	5.6	+7.2	14.6	-3.4	46	-32	0.81	-0.17	8.1
Minnedosa, Man.	1,000	28.05	29.96	-0.13	4.8	+7.5	15.0	-5.5	47	-31	0.31	-0.30	3.1
Le Pas, Man.	860				-1.0		9.2	-11.3	44	-36	0.88		8.8
Qu'Appelle, Sask.	2,115	27.66	29.92	-0.16	8.7	+0.3	18.0	-0.6	57	-26	0.59	-0.14	5.9
Moose Jaw, Sask.	1,759				11.5		23.1	-0.1	64	-29	0.29		2.9
Swift Current, Sask.	2,392	27.23	29.89	-0.18	13.6	+5.6	24.4	2.7	62	-27	0.34	-0.40	3.4
Medicine Hat, Alb.	2,365	27.34	29.92	-0.13	14.9	+3.7	26.2	3.7	63	-32	0.70	+0.03	6.6
Banff, Alb.	4,521	25.12	29.85	-0.13	18.5	-0.7	27.9	9.1	47	-38	1.61	+0.69	5.1
Prince Albert, Sask.	1,450	28.33	30.00	-0.09	1.3	+4.3	10.6	-8.0	51	-45	0.31	-0.38	3.1
Battleford, Sask.	1,592	28.14	29.98	-0.11	0.5	+0.4	11.0	-10.0	48	-49	0.02	-0.35	0.2
Edmonton, Alb.	2,150	27.47	29.87	-0.15	9.2	+0.9	18.7	-0.4	56	-35	0.80	+0.13	7.1
Kamloops, B. C.	1,262	28.64	29.97	+0.01	23.8	-1.5	34.1	19.6	62	-16	0.22	-0.57	2.2
Victoria, B. C.	230	29.76	30.02	+0.02	40.4	+0.9	44.4	36.4	55	20	6.29	+2.19	T.
Estevan Point, B. C.	20				33.0		43.4	32.7	48	17	14.63		T.
Prince Rupert, B. C.	170				35.3		38.7	31.9	47	17	11.81		14.5
Hamilton, Ber.	151	29.91	30.08	-0.03	61.9	+0.4	68.1	55.7	75	49	2.86	-1.58	0.0

## LATE REPORTS, JANUARY, 1932

Cape Race, N. F.	99				24.8		31.7	17.9	51	-6	3.74		10.7
Sydney, C. B. I.	48	29.93	29.98	+0.05	28.0	+7.5	34.6	21.4	49	12	4.78	-0.32	21.0
Halifax, N. S.	88	29.93	30.04	+0.07	29.2	+7.4	37.3	21.0	57	-3	5.97	+0.20	16.8
Yarmouth, N. S.	65	29.94	30.01	+0.01	31.8	+5.5	38.2	25.4	50	8	6.90	+1.74	23.1
Charlottetown, P. E. I.	38	29.92	29.96	.00	25.1	+8.1	31.9	18.3	51	2	5.54	+1.58	20.1
Chatham, N. B.	28	29.90	29.94	-0.03	20.7	+10.9	31.3	10.2	62	-15	2.15	-1.44	7.4
Father Point, Que.	20	30.00	30.03	+0.03	17.8	+9.8	25.3	10.2	42	-10	2.46	-0.30	14.4
Parry Sound, Ont.	688	29.31	30.02	+0.01	28.0	+14.2	34.1	21.9	50	-2	4.36	+0.28	21.9
Winnipeg, Man.	700	29.17	30.05	-0.06	6.3	+13.1	14.4	-1.9	35	-29	1.34	+0.46	13.4
Qu'Appelle, Sask.	2,115	27.63	29.99	-0.09	5.5	+9.3	14.6	-3.5	40	-33	0.62	+0.12	6.2
Medicine Hat, Alb.	2,365	27.43	29.92	-0.05	11.8	+6.3	20.4	3.3	42	-27	0.46	-0.11	4.0
Calgary, Alb.	3,540	26.14	29.97	-0.06	13.9	+5.5	22.9	5.0	48	-27	0.40	-0.13	4.0
Banff, Alb.	4,521	25.23	30.03	+0.03	10.6	-1.5	19.1	2.2	38	-28	1.14	-0.05	11.4
Edmonton, Alb.	2,150	27.66	29.97	-0.06	5.7	+3.9	14.4	-2.9	44	-42	0.55	-0.13	5.5
Kamloops, B. C.	1,262	28.78	30.13	+0.17	22.7	-0.3	27.4	18.0	47	-10	0.17	-0.65	1.0
Estevan Point, B. C.	20				37.9		42.9	33.0	48	18	11.46		6.5
Prince Rupert, B. C.	170				33.5		37.0	30.0	47	12	13.03		6.2
Hamilton, Ber.	151	30.11	30.28	+0.15	64.8	+2.8	70.9	58.8	76	54	1.63	-3.31	0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, February, 1932

Chart I. Departure (°F.) of the Mean Temperature from the Normal, February, 1932

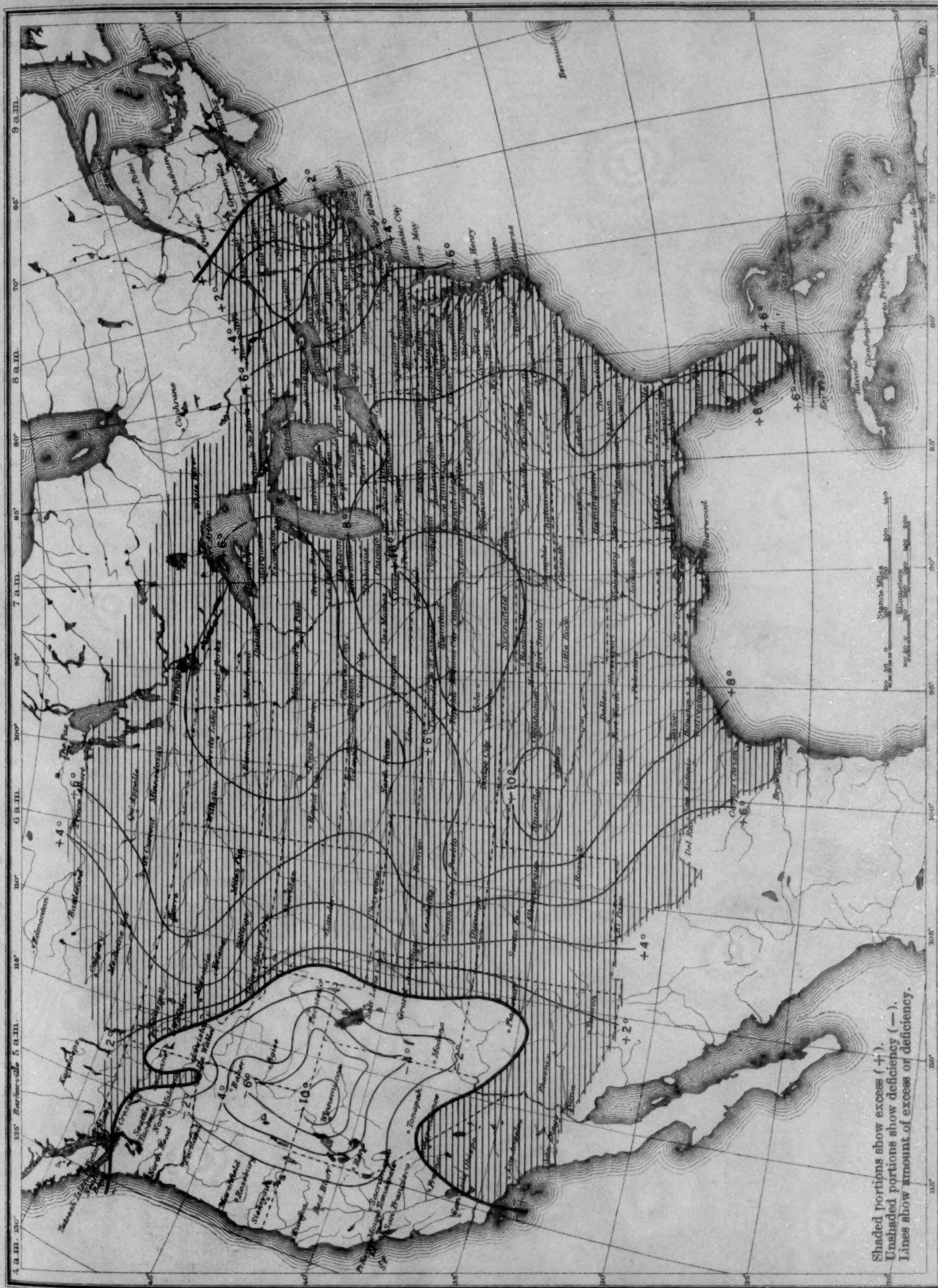
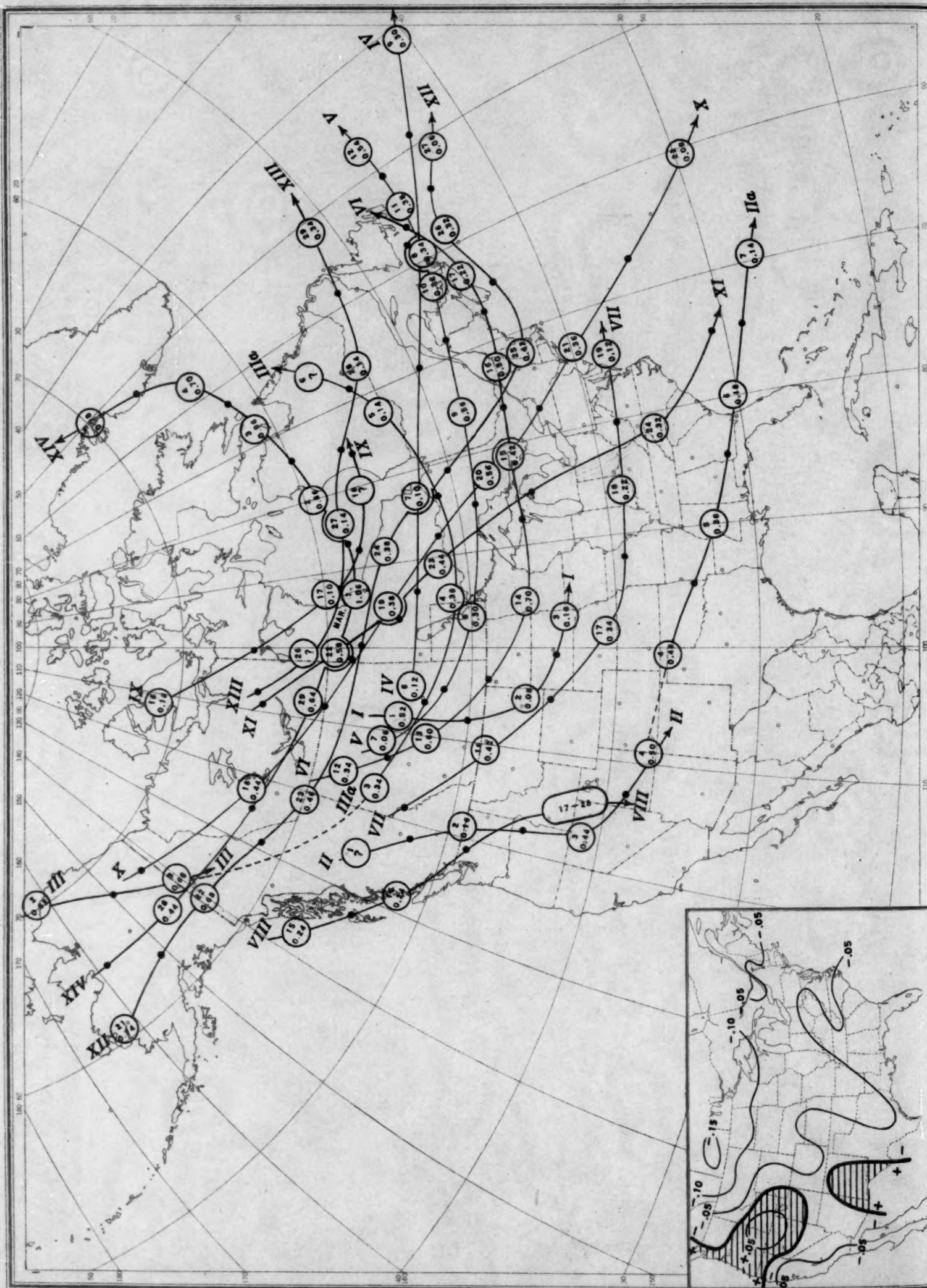


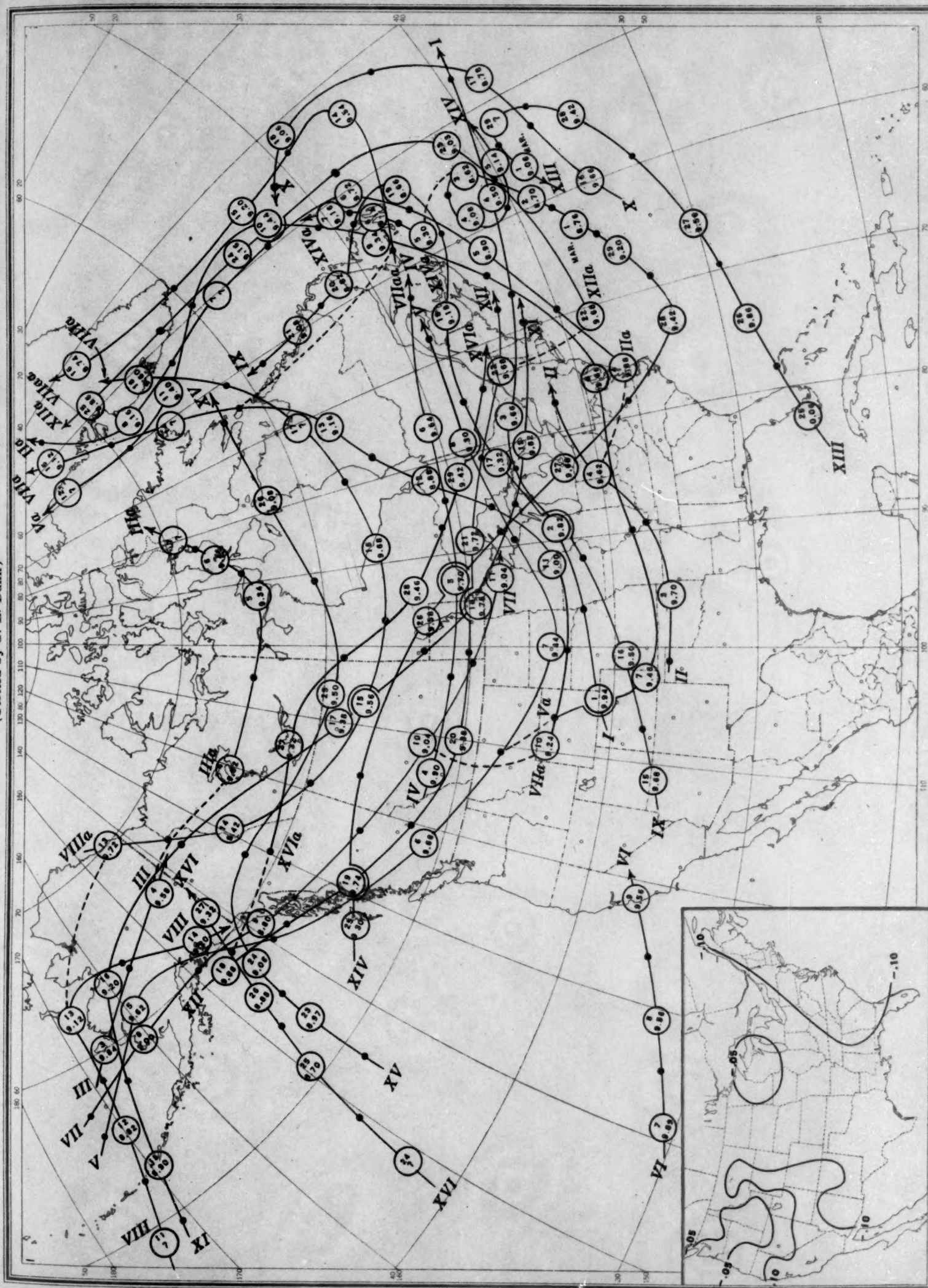
Chart II. Tracks of Centers of Anticyclones, February, 1932. (Inset) Departure of Monthly Mean Pressure from Normal  
(Plotted by G. E. Dunn)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, February, 1932. (Inset) Change in Mean Pressure from Preceding Month  
(Plotted by G. E. Dunn)

Chart III. Tracks of Centers of Cyclones, February, 1932. (Inset) Change in Mean Pressure from Preceding Month  
(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).



Chart IV. Percentage of Clear Sky between Sunrise and Sunset, February, 1932

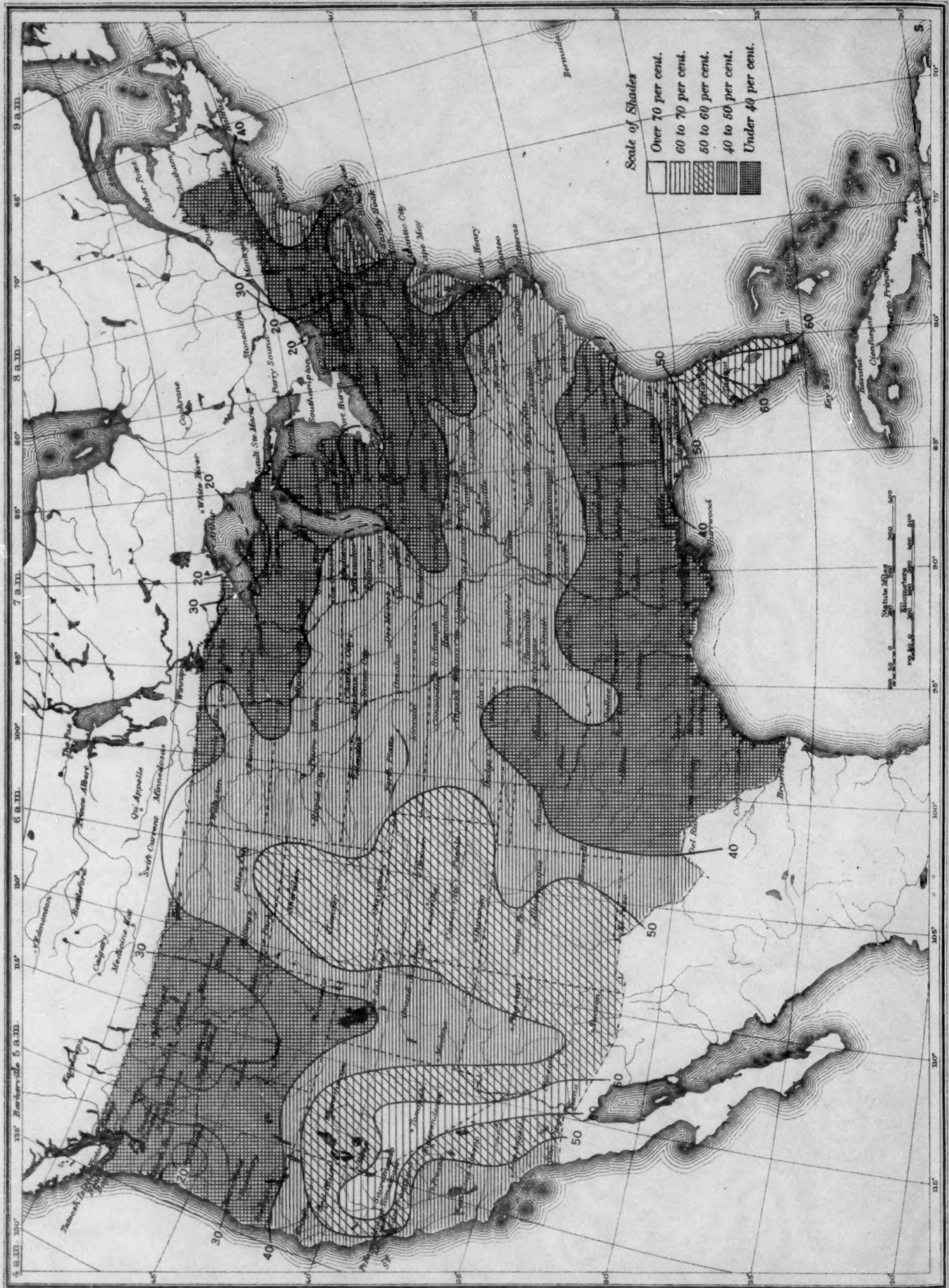


Chart V. Total Precipitation, Inches, February, 1932. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, February, 1932. (Inset) Departure of Precipitation from Normal

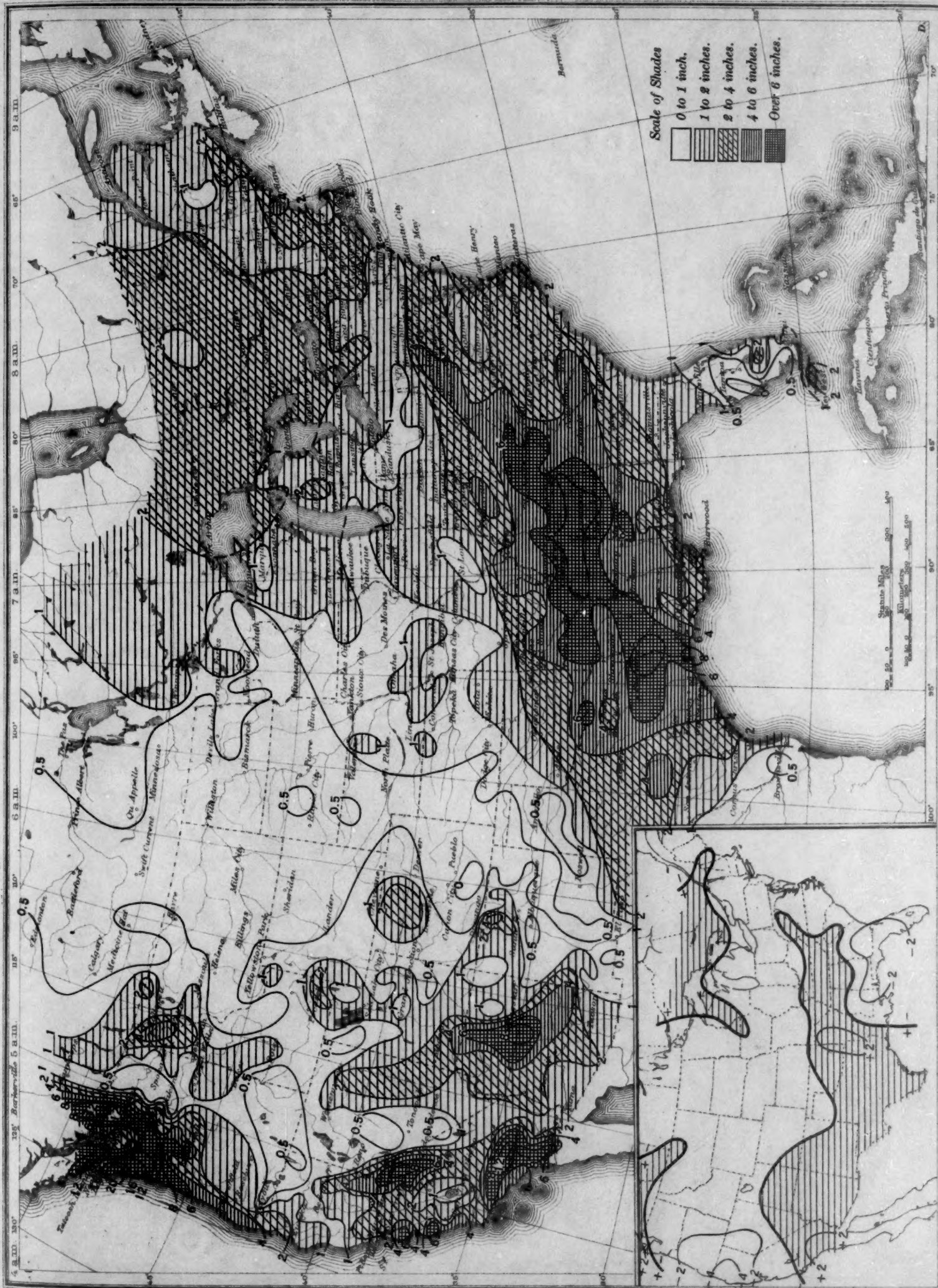


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, February, 1932

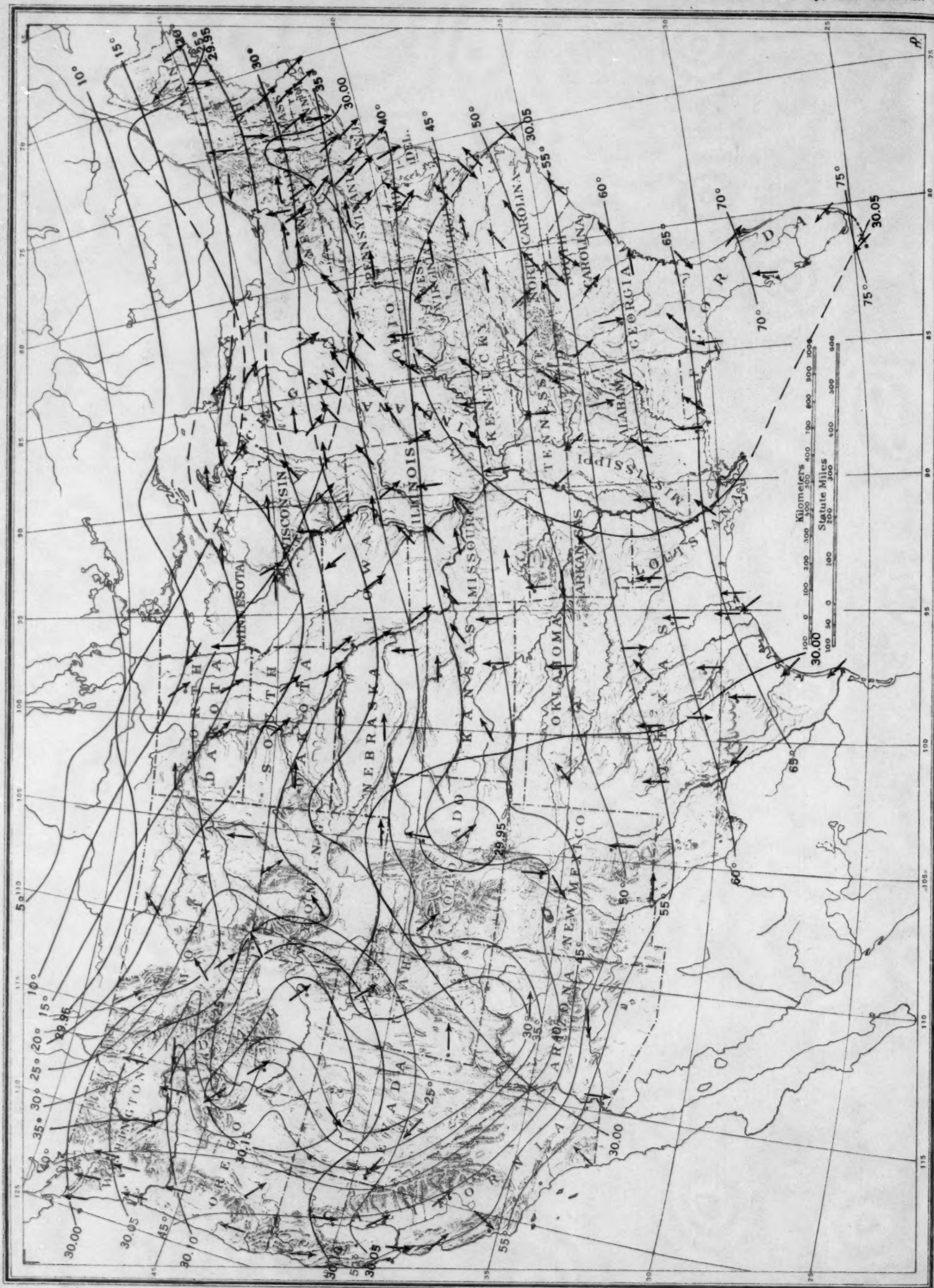


Chart VII. Total Snowfall, Inches, February, 1932. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, February, 1932. (Inset) Depth of Snow on Ground at end of Month

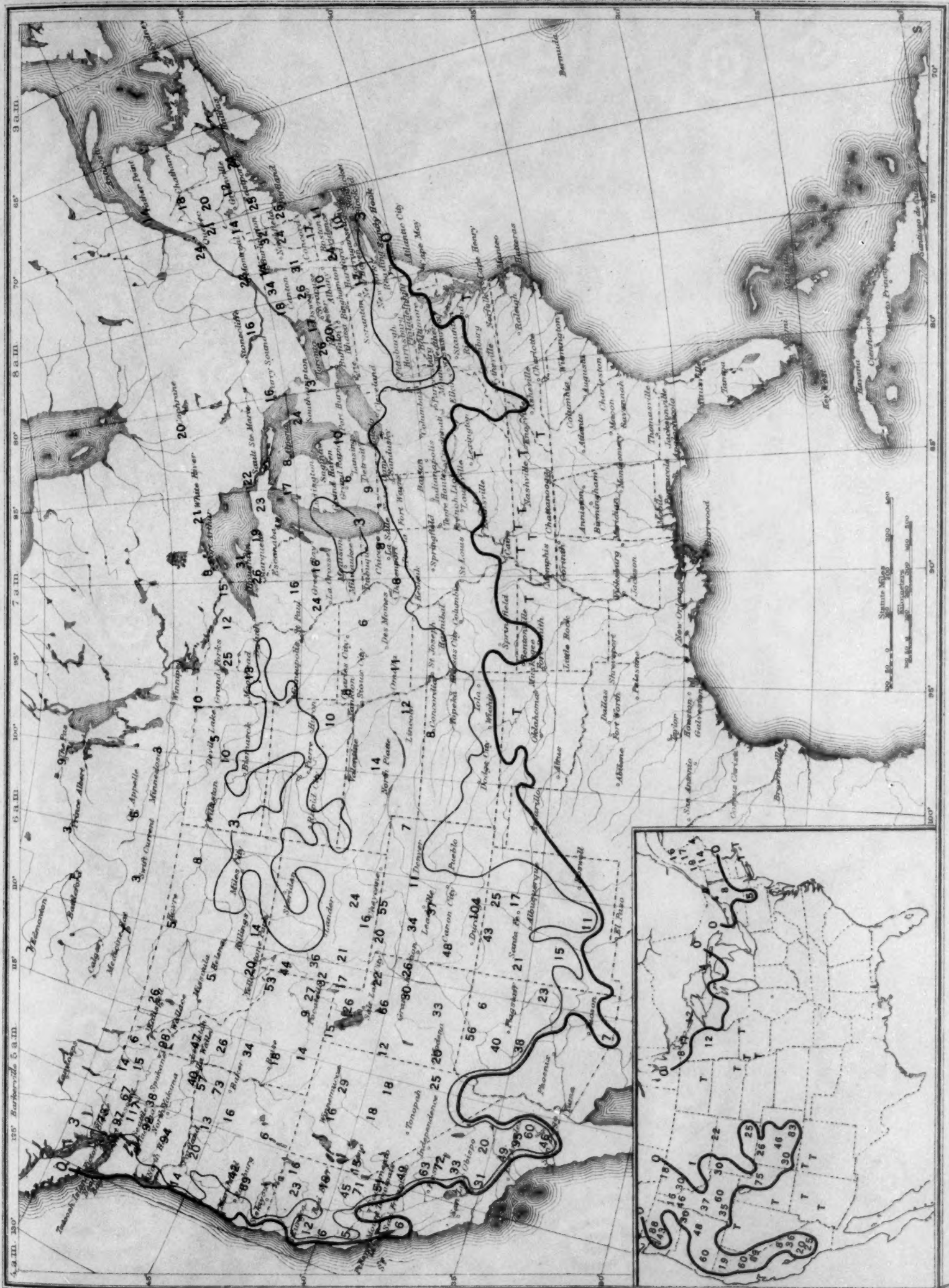




Chart VIII. Weather Map of North Atlantic Ocean, February 3, 1932  
(Plotted from the Weather Bureau Northern Hemisphere Chart)

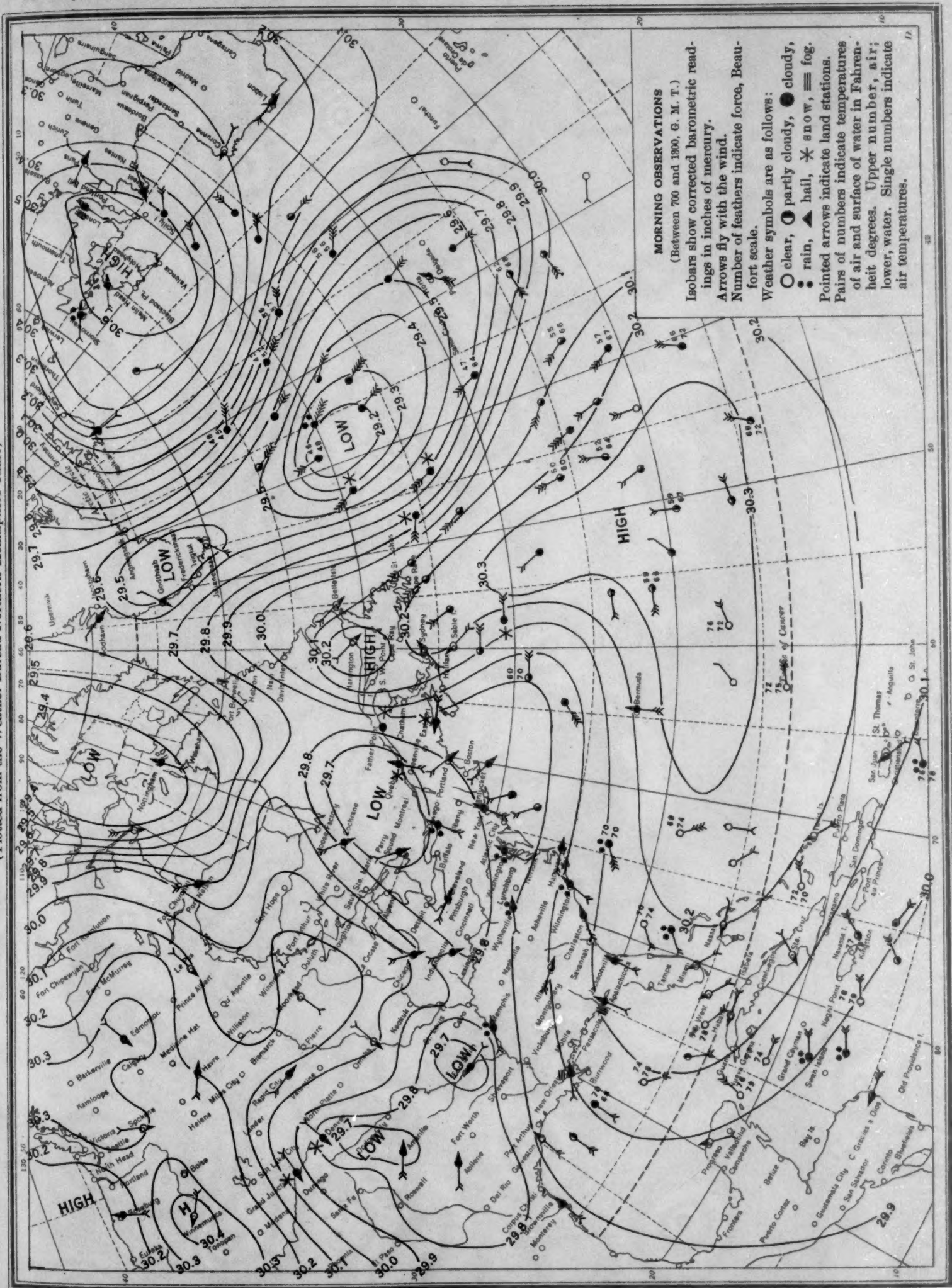


Chart IX. Weather Map of North Atlantic Ocean, February 4, 1932  
(Plotted from the Weather Bureau Northern Hemisphere Chart)

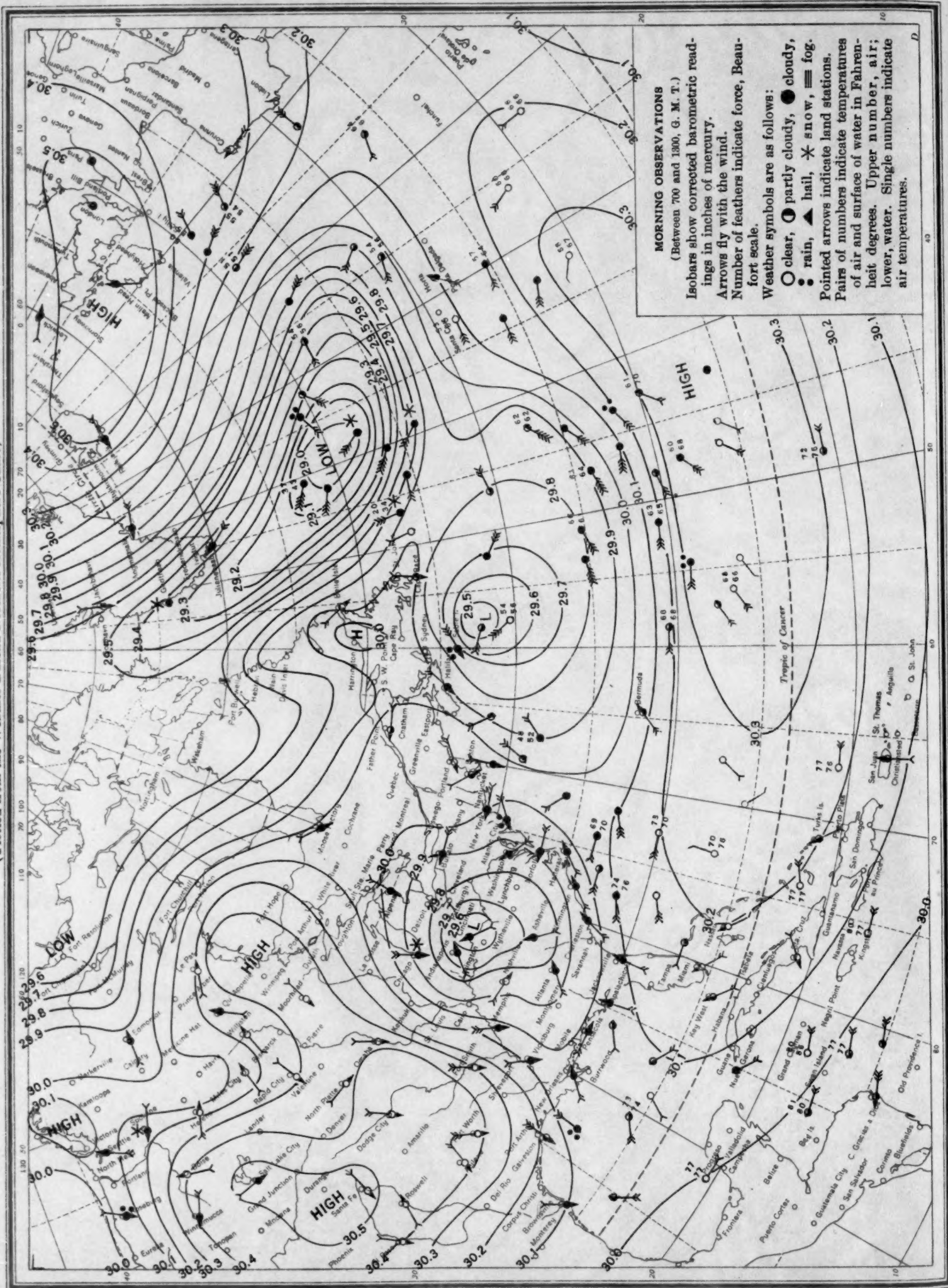


Chart X. Weather Map of North Atlantic Ocean, February 5, 1932  
(Plotted from the Weather Bureau Northern Hemisphere Chart)

Chart X. Weather Map of North Atlantic Ocean, February 5, 1932  
(Plotted from the Weather Bureau Northern Hemisphere Chart)

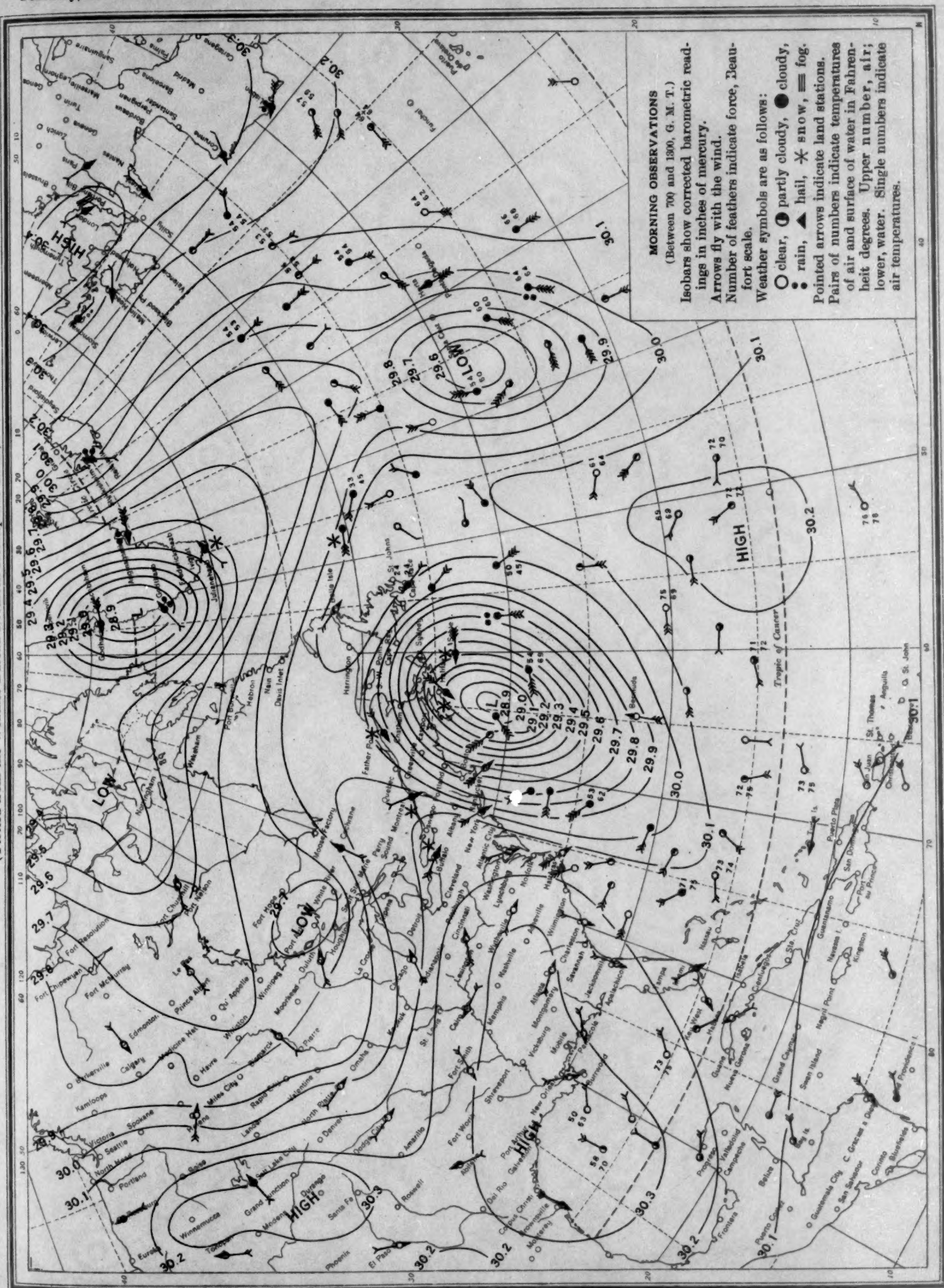


Chart XI. Weather Map of North Atlantic Ocean, February 6, 1932  
(Plotted from the Weather Bureau Northern Hemisphere Chart)

